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Effects of Heat Stress and an Encumbered Aviator Uniform on Flight Performance in a UH-60 Helicopter Simulator

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The effects on flight performance of the four combinations of an unencumbered level-zero mission oriented protective posture (MOPP) 0 aviator battle dress uniform (ABDU) and encumbered MOPP4 over ABDU flight ensemble in cool (70°F, 50 percent relative humidity [RH]) and hot (100°F, 50 percent RH) UH-60 simulator cockpit conditions were evaluated with a repeated measures, 2 by 2 factorial study using nine crews. This report describes the flight performance results; a previous report provided detailed analysis of the physiological and psychological responses. The use of detailed flight scripts and performance criteria for each type of maneuver maintained uniformity for flight performance evaluation across the four test conditions. Every 30 minutes, the right seat pilot encountered instrument meteorological conditions and ascended to 2000 feet to perform a 10-minute set of standard maneuvers. These maneuvers included straight and level (SL), right standard rate turn (RSRT), left climbing turn (LCT), and left descending turn (LDT). After each iteration of the set of standard maneuvers, the pilot returned to nap-of-the-earth (NOE) and contour flight between control points. The right seat pilot also performed four 1-minute hovers (HOVs) and hover turns (HOVTs) in the first 2-hour

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sortie and three in the second 2-hour sortie. The simulator's data acquisition system captured relevant combinations of airspeed, altitude, turn and climb rates, trim, and roll for each type of flight maneuver, as well as cyclic and collective inputs during HOV and HOVT. When averaged across iterations of flight maneuvers flown with either the automatic flight control system fully engaged (AFCS on) or with the trim and flight stabilization components turned off (AFCS off), the encumbered MOPP4 uniform was associated with reduced ($p<0.05$) averaged composite scores (ACS) for five (HOV, HOVT, RSRT, SL, and contour) of eight (62.5 percent) maneuvers. ACS values were significantly lower for 5 of 29 (17.2 percent) separately scored flight systems parameters. The hot temperature condition, as a main effect, reduced the ACS for only one (RSRT) of eight maneuvers. For the iterations of the maneuvers flown with AFCS on, the encumbered MOPP4 ensemble was associated with significantly lower ACS for 3 (HOV, HOVT, and contour) of 8 (37.5 percent) maneuvers and 5 of the 29 (17.2 percent) separately scored flight parameters. With AFCS off, the encumbered MOPP4 uniform significantly degraded the composite ACS for 2 (SL and LDT) (50 percent) of 4 maneuvers (SL, RSRT, LCT, and LDT) comprising the set of standard maneuvers that were alternately flown with AFCS off and 5 of 17 (29.4 percent) separately scored flight parameters. The hot temperature was associated with reduced composite ACS values for two (RSRT and LCT) of the four flight maneuvers. The encumbered MOPP4 uniform had the most frequent adverse effect on flight performance followed by heat stress with less frequent effects from the combination or interaction of these two factors. There were no statistically significant increases in simulator crashes, main rotor or stabilator strikes, or other recorded incidents for the hot or encumbered MOPP4 conditions. Flight parameter scores were more sensitive in detecting differences in simulator performance across test conditions than root mean square errors or maximum and minimum deviations from target performance values. This study confirmed that heat stress and wearing an encumbered U.S. Army MOPP4 flight uniform significantly reduced endurance and flight performance in a UH-60 simulator.

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Introduction

During hot weather, aviators are often exposed to substantial heat stress outdoors during preflight duties and while flying unair-conditioned aircraft. The environmental components of heat stress include ambient temperature, humidity, wind speed, and radiant heat load. Such measures can be combined into a single indicator such as the wet bulb globe temperature (WBGT). The WBGT is a weighted sum of three temperatures: (0.7 x naturally convected wet bulb temperature) + (0.2 x black globe temperature) + (0.1 x shaded dry bulb temperature).

The wet bulb temperature accounts for the effects of humidity and wind on heat stress. The black globe accounts for radiant heat loads from solar and other sources, and the shaded dry bulb accounts for the intrinsic thermal content of the ambient air. The coefficients, or weights, in the WBGT formula above, determine the relative contribution of the environmental components represented by the three methods of temperature measurement to heat stress for humans. One of the most useful aspects of the WBGT is that the different combinations of wet bulb, dry bulb, and black globe temperatures resulting in identical WBGT values define conditions of equivalent heat stress. A local ambient WBGT is a relatively good predictor of physiological heat strain and probability of heat illness except when very occlusive, impermeable clothing or overgarments are worn. In the latter situation, a significant disparity can develop between the WBGT in the microclimate of the highly saturated air layer between the skin and inner layer of clothing (usually not measured) and the ambient WBGT.

Numerous field studies have confirmed the frequent occurrence of very elevated cockpit temperatures in helicopters exposed to hot weather conditions. Breckenridge and Levell (1970) documented WBGTs greater than 104°F and dry bulb air temperatures up to 132°F in the closed cockpit of a stationary AH-1G attack helicopter parked in the direct sun during summertime at a military facility in Georgia. Froom et al. (1991) showed that during standby for takeoff, cockpit WBGT in a Bell 212 helicopter initially was 2.9 ± 3.7°C, and after 1 hour 7.2 ± 3.5°C, higher than ambient WBGT. In a study by Thornton and Guardiani (1992), WBGTs in the cockpit of a hovering UH-60 transport helicopter with doors and windows closed during summertime were approximately 5°C higher than airfield WBGTs (approximate range: 28-35°C or 82.5-95°F). In contrast, cockpit and airfield WBGTs did not differ much during contour flight.

These data are of great concern because U.S. Army aviators frequently train or deploy to areas in the United States or overseas with very hot summer climates and intense solar radiation. Furthermore, operational requirements in such locations may necessitate that pilots don overgarments and personal survival components to protect against ballistic, chemical, or biological (CB) threats. Additionally, during aviation operations in CB threat scenarios pilots may also need to fly with closed aircraft doors and windows in order to minimize ingress of potentially lethal CB warfare agents into

the aircraft cabin. In hot weather conditions, or in moderate temperature conditions with high humidity or intense solar load, a closed unair-conditioned helicopter cockpit will result in heat stress even if crewmembers wear unencumbered, light weight, standard issue flight uniforms. The addition of relatively occlusive and cumbersome overgarments and protective equipment will additively or synergistically exacerbate the ambient heat stress. There are multiple potential sources of heat stress within helicopter cockpits including heat transfer into the cockpit from the external environmental and direct solar radiation, increased cockpit air temperature from the greenhouse effect, as well as intrinsic conduction and radiation of heat from internal thermal sources such as engines, auxiliary power units, and various electronic systems.

In general, heat stress induces many complex and interrelated compensatory physiological and biochemical thermoregulatory changes, or adaptations, which are collectively termed heat strain (Wyndham, 1973). Although the adverse performance effects of mild to moderate heat stress in laboratory studies and field evaluations have often been relatively small and their operational significance not well defined, it is common knowledge that incapacitating heat illness will occur if thermal stress is sufficiently intense or the exposure excessively prolonged. Obviously, inflight heat exhaustion and heat stroke are emergencies that will result either in a crash for a single pilot aircraft, or require an immediate landing or diversion of missions to the nearest medical unit for a two pilot aircraft. Heat stress is a ubiquitous and potentially serious threat that should not be underestimated by aircrews. Since pilots are frequently responsible for the lives of many passengers during a mission, it is incumbent on them and aviation unit leaders to minimize the risk of heat stress related impairment of aircrew health and performance.

General effects of heat stress on task performance

There are a multitude of references in literature on the effects of heat stress on various types of performance. Most, however, have reported results only for relatively simple mental, cognitive, or other perceptual tests, time estimation, reaction time, tracking, and vigilance. Some papers have presented results of more complex real-world tasks such as operating vehicles. The relationships between performance on simple tasks and highly complex tasks such as piloting military helicopters have not been well defined or validated. Furthermore, results from different studies have frequently been contradictory or of questionable significance because of the occurrence of relatively small performance differences across the different levels of the principal factors (which frequently were not well controlled).

In a review of reports published between 1979 and 1991, Ramsey (1995) elucidated a number of potential reasons for variance in findings across different heat stress and performance studies. In most of the reported studies, many potential confounders were not controlled for, nor were sufficient data collected on them to allow adjustment for

their effects during statistical analysis. Some of the potential confounders listed by Ramsey include: core temperature, effects of task variations, extent of acclimatization, state of mental acuity and interest, amount of previous training and skill levels, type of clothing, variations in work load, comfort, and cumulative stress load.

The principal conclusions regarding the effects of heat stress exposure on task performance in the review by Ramsey were that mental and simple motor tasks are not affected much by heat stress, whereas performance on more complex psychomotor tasks becomes adversely affected, in a statistically significant sense, when ambient WBGTs reach or exceed the 30-33°C (86-91.4°F) range. Many studies have indicated performance decrements occurring soon after exposure to intense heat stress conditions even before core temperature had time to rise significantly. This indicates that heat stress intensity, as well as duration of exposure, interact to impact negatively on task performance. Ramsey points out, however, that few studies determined whether there was an association between statistically significant decrements in performance found in laboratory studies and operationally significant performance decrements that would affect mission accomplishment, safety, or accident rates.

Ramsey's meta-analysis did not lead to any quantitative description of the relationship between the severity of heat stress and degree of performance decrements. However, Berglund et al. (1990), provide an example of a model based on data from a British Navy study that evaluated the effects of heat stress on error rates for decoding Morse code. That quantitative model indicated a subjective thermoneutral air temperature of 25°C (77°F). At greater air temperatures, it predicted a linear increase in thermal discomfort ratings. Similarly, decoding error rates were predicted to increase in a near-linear manner above 26°C (78.8°F).

Kobrick and Johnson (1992) also presented a review of the literature on the effects of heat stress and performance that included many references published prior to 1979. Although this review also revealed some conflicting results between studies evaluating similar tasks under similar conditions, as conditions became more thermally stressful, results became more consistent. At higher levels of thermal stress, decrements in visual and auditory vigilance, marksmanship, pointer alignment, manual tracking, 5-choice task, and short term memory became apparent.

Hancock (1982) presented a graphical depiction of the amount of core temperature elevation (as a function of effective temperature and exposure time) required to cause significant decrements in performance for three different task categories (dual task, tracking, and mental). His analysis indicated that core temperature increases of only 0.4°F, 1.6°F, and 3.0°F would be sufficient to cause observable decrements in dual task performance, tracking, and mental tasks, respectively. The hotter the ambient conditions, the sooner these core temperature thresholds and associated performance

decrements become apparent. The task performance was affected according to their degree of response complexity.

It has been generally recognized that a higher level of skill in performing a complex task is partially protective against heat stress induced performance decrements. This is probably because the more a task is practiced, ingrained, and understood, the less the implicit response complexity. Requirements for intense concentration on the various aspects of a task and the need for continuous real-time cognitive decision making regarding the details of the task are diminished with increasing skill. Therefore, greater skill with a particular task effectively reduces the task difficulty and makes it less susceptible to the effects of heat stress.

Effects of CB protective ensembles on performance

MOPP is a military acronym for mission oriented protective posture. It is associated with four levels of increasing personal protection against CB threats. Commanders designate what MOPP level is appropriate for their units based primarily on estimates obtained from intelligence sources on the nature and immediacy of CB threats. MOPP components include a CB absorbent overgarment, CB mask, and impermeable hood, gloves, and boots. All of these components are worn simultaneously for level four MOPP (MOPP4) CB protection. Although there has been a continuous but slow evolution in the design and biophysical properties of MOPP4 components, complete MOPP4 ensembles are still bulky, encumbering, and prevent efficient thermoregulation.

Taylor and Orlansky (1993), after an extensive review of the literature, provided a comprehensive summary of the effects of MOPP4 on individual and unit performance. On an individual basis, CB masks typically impair vision, auditory acuity, and speech transmission. Visual difficulties while wearing CB masks may contribute to longer scan times and more difficult tracking when engaged in target search and track activities. CB masks also increase the work of breathing, respiratory function, and can elicit anxiety, claustrophobic reactions, and hyperventilation (Muza et al., 1995). The butyl rubber gloves have been associated, in laboratory tests, with significantly increased completion times for manual dexterity tasks. Lussier and Fallesen (1987) showed that MOPP4 caused an 8 percent performance decrement on 11 computer keyboard tasks. Task training or practice while in MOPP4 can reduce some of its adverse effects on performance.

United States Army Aeromedical Research Laboratory (USAARL) evaluations of heat stress, CB ensembles, and flight performance

Hamilton et al. (1982) performed a study to delineate the effects of three different aviator ensembles on UH-1 flight performance during hot weather conditions. The uniforms tested included what was then the standard aircrew battle dress uniform (ABDU) MOPP0 and MOPP4 U.S. Army aviator uniforms and a British MOPP4 flight ensemble. Six volunteer UH-1 pilots participated in the repeated measures, fully counterbalanced, study design. However, due to aircraft problems, data for only four pilots were available for analysis. Three types of maneuvers were flown: straight and level, lateral hover with hover turns at specified locations, and a 50- foot hover. Analysis of error data for the measured parameters did not reveal significant flight performance differences between the three different uniforms.

Knox et al. (1983) recruited eight aviators to compare the physiological, psychological, and flight performance effects of aviators wearing either a standard ABDU MOPP0 flight uniform or a MOPP4 ensemble. Inflight testing was performed in a UH-1 helicopter during hot summer weather. Comparisons of root mean squared (RMS) flight performance errors for the standard uniform and nuclear, biological and chemical (NBC) ensemble are summarized in table 1 below.

Table 1.
Flight performance RMS errors (Knox et al., 1983).

Performance Parameter	Standard Flight Uniform	NBC Ensemble
Heading error (degrees)	1.63	2.02
Airspeed error (knots)	1.83	2.19
Time to complete maneuvers error (secs)	0.93	1.08
Straight flight heading error (degrees)	1.47	1.58
Straight flight airspeed error (knots)	1.27	1.86

None of the differences in RMS errors across type of flight uniform reached statistical significance at the $p \leq 0.05$ level. However, there did seem to be a trend (6/8 test subjects) for somewhat worse performance for the MOPP4 ensemble. Again, the statistical power available in the analysis was not discussed. As in Hamilton's study, there also was no test to determine whether the distribution profile of environmental conditions for test iterations were statistically different across the two different uniforms. Inflight turbulence, which was not estimated, could have been a source of increased variance in flight performance that obscured main effects. Unmeasured variations in

ambient and cockpit temperatures, humidity, and solar load could also have contributed to variance in the measures. An experimental design was required where these potentially obfuscating sources of variance in flight performance could either be eliminated or controlled.

Thornton et al. (1992) completed a comparative evaluation of flight performance in the USAARL UH-60 simulator for two flight uniforms in two carefully controlled environmental conditions. The uniforms were a standard one-piece U.S. Army MOPP0 flight uniform versus a MOPP4 aircrew uniform integrated battlefield (AUIB) ensemble encumbered with ballistic plate and various ancillary items of personal survival equipment. Cockpit WBGT in the UH-60 simulator was 17.9°C (64.2°F) for the cool, or baseline, condition and 30.6°C (87.1°F) for the hot condition. Flight performance data revealed significant differences across the four test conditions for 46 percent of the combinations of measured navigational parameters and maneuver type. The most consistent statistically significant differences in flight parameter RMS errors across the test conditions occurred for heading, vertical speed, rate of turn, airspeed, roll and altitude, in that order. Differences in RMS slip errors were not consistent across the four test conditions. Maximum RMS errors for heading and altitude were significantly greater for the MOPP4 AUIB-hot condition. Disconnecting the trim and flight stabilization components of the automatic flight control system had an independent effect of increasing flight parameter errors, except for roll error, which was paradoxically reduced.

The main effect of heat stress for the aviators wearing the MOPP4 AUIB was a statistically significant increase in RMS error for some flight performance parameters. In an absolute sense, however, the RMS errors were not very large. It was proposed that maximum, rather than RMS, flight parameter error might be a more accurate predictor of operationally significant decrements in flight performance such as those (e.g., infrequent but large altitude deviations) that could directly lead to aircraft accidents (e.g., crashing into terrain or obstacles). This line of reasoning was reinforced when significant flight incidents were tabulated and analyzed. Seven crashes occurred during the UH-60 simulator sessions. These were primarily due to the aviators flying into terrain or trees. Six of the seven accidents occurred while wearing the MOPP4 AUIB ensemble. Four of those occurred in the hot condition and two in the cool condition.

Current U.S. Army aviator ensembles include the two-piece ABDU, as well as the battle dress overgarment (BDO). The BDO is worn over the ABDU to protect against CB warfare threats. In an encumbered configuration, an aviation life support equipment (ALSE) vest, a laminated ballistic protection plate, and overwater personal floatation devices are also worn over the BDO. Previously reported physiological results from this study conclusively showed that, in hot conditions, the bulky encumbered MOPP4

ensemble is uncomfortable and significantly impairs thermoregulation and heat dissipation (Reardon et al., 1996).

Reardon et al. (1996) describes the effects of cockpit heat stress and the two flight ensembles (the unencumbered MOPP0 ABDU and encumbered MOPP4 BDO over ABDU) on UH-60 simulator flight performance and workload ratings. The study was conducted between 25 March - 2 August 1996 to fulfill collaborative U.S. Army Aviation and Troop Command (ATCOM)-USAARL objectives in a governing statement of work (SOW, USAARL, 1995). The primary objectives of the study were:

1. Develop and test a general methodology for evaluating the extent to which aviator ensembles contribute to heat strain and affect flight performance, mission accomplishment, endurance, and mood states in hot versus temperate UH-60 simulator cockpit conditions.

2. Establish a baseline heat stress effects profile for current unencumbered and encumbered aviator ensembles against which future enhanced versions of those ensembles may be compared as they are developed under the aegis of the Air Warrior Program Manager, Aircrew Integrated Systems, ATCOM, St. Louis, MO.

Methods and procedures

Study design

This study utilized military helicopter pilots in a two-by-two factorial, repeated measures, partially counterbalanced, unblinded experimental design to evaluate the direct and interaction effects of two types of current aviator uniform (unencumbered MOPP0 ABDU vs. encumbered MOPP4 over ABDU) and two cockpit thermal conditions (cool vs. hot) on flight performance in a UH-60 simulator, performance on a computerized multi-task test, and work load ratings. Flight performance data were obtained from nine different pilots and performance data for the multi-task computer test were obtained from a different set of eight pilots. Work load ratings were obtained from all the pilots.

Environmental conditions

The cool simulator condition consisted of a dry bulb temperature (T_{db}) of 70°F (21.1°C) and 50 percent relative humidity (RH). The hot condition utilized a T_{db} of 100°F(37.8°C) and 50 percent RH. The WBGT values for the two conditions in the simulator included the effects of radiant energy emitted by three sets of heat lamps situated above each pilot's helmet. The two banks of three heat lamps each, located in

the simulator ceiling above each pilot's seat, were set at 50 percent maximum output (see appendix J for the heat lamp's spectral output). Conditions in the environmental chamber during the 20-minute simulated preflights had the same temperature settings but lower relative humidity (20 percent). It was not feasible to install heat lamps in the environmental chamber. Humidity in the UH-60 simulator was set at a higher value to emulate the increase in humidity that occurs when doors and windows are closed in an actual UH-60 in similar ambient environmental conditions.

Flight uniforms

Table 2 lists the components of the two aviator ensembles utilized in this study, and is followed by figure 1, which depicts test subjects wearing the encumbered MOPP4 BDO over ABDU ensemble.

Table 2.
Air Warrior heat stress study aviator ensembles.

ITEMS	Unencumbered MOPP0 ABDU	Encumbered MOPP4 BDO over ABDU
HGU-56P	x	x
ABDU	x	x
Combat boots	x	x
Flight gloves (summer light)	x	x
Kneeboard	x	x
SARVIP vest with mod	x	x
SARVIP 0.50 cal armor		x
SARVIP packs		x
M43A1 CB Mask		x
BDO		x
PRC-112A survival radio		x
LPU-21 a/P water wings		x
LRU-18P raft		x
SRU-37/P container (raft)		x
HEED		x

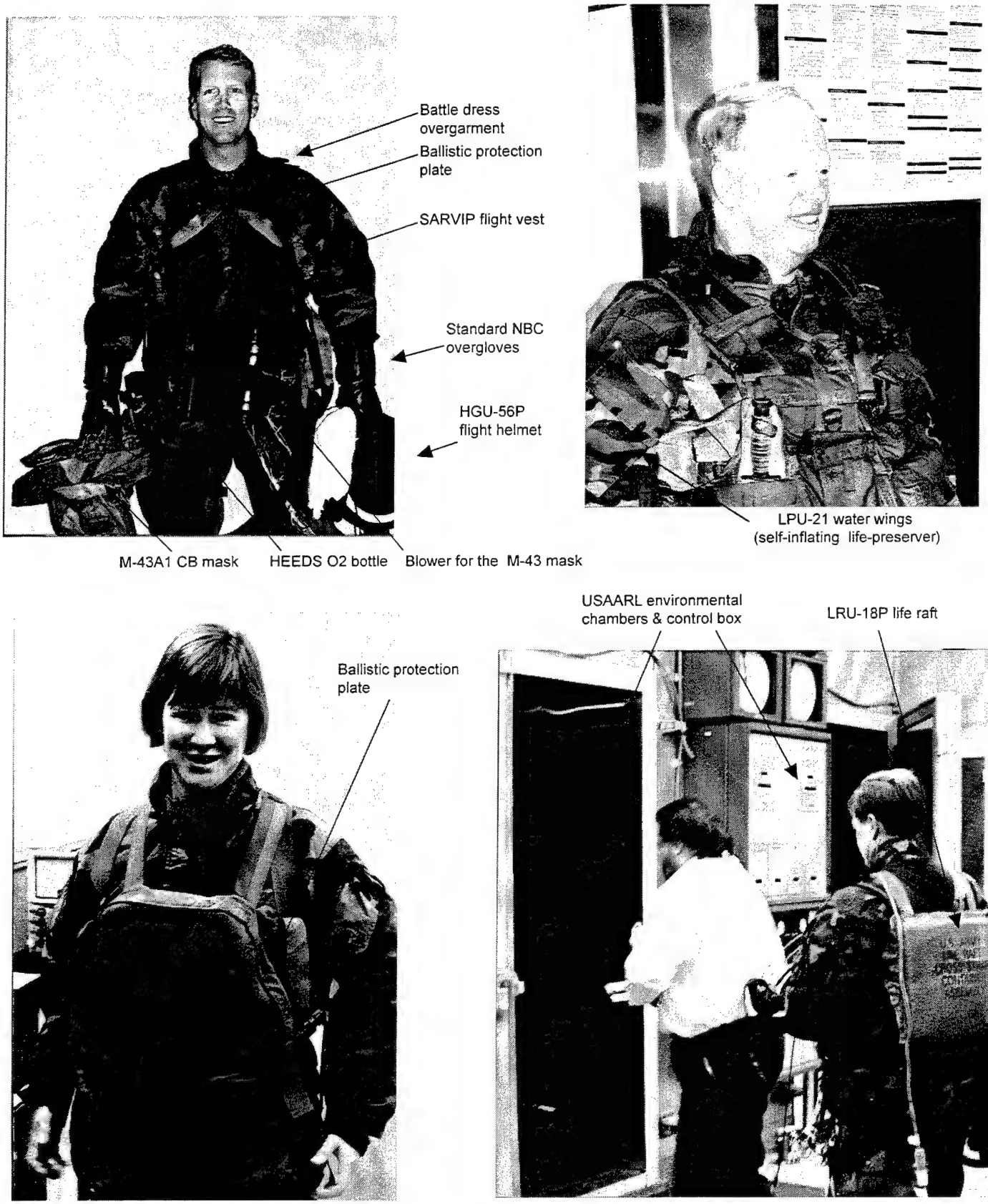

Figure 1. Photos of the aviator uniform components.

UH-60 helicopter simulator

The USAARL UH-60 research simulator was used for obtaining flight performance measurements. Its hydraulic motion base provides 6 degrees freedom of motion allowing for acceleration cues in the lateral, longitudinal, vertical directions and allowing pitch, roll, and yaw over a 60 degree range. The simulator has a three-channel, four-window, digital image generator (DIG). Using digitized terrain map data, the DIG continuously generates three separate, but synchronized, out-the-cockpit video scenes displayed by four cathode ray tube (CRT) units. The forward scenery is displayed by the CRT in each of the front windscreens while the left and right scenery are transmitted to the CRT for their respective cockpit window.

The UH-60 research simulator is equipped with an environmental control unit (ECU) that maintains specified target dry bulb temperature and RH in the cockpit during the study. The ECU is capable of controlling cockpit conditions within a range of 68-105 °F (± 3 °F) and 50-90 percent RH (± 3 percent).

The flight instruments and controls in the UH-60 simulator were directly linked to a real-time data acquisition system controlled by a Digital Equipment Corporation (DEC) VAX 11/780 computer[1]*. This 128 channel, automated data acquisition system continuously captured flight performance data at a 30 hertz (Hz) sampling rate (USAARL, HAWK Manual, 1991). The system continuously recorded cockpit instrument data such as airspeed, altitude, roll, pitch, and slip. Cyclic and collective inputs during hover and hover turn maneuvers were also automatically recorded at a 10 Hz sampling rate. These flight data were stored on magnetic media linked to a DEC-VAX computer system. The data were then downloaded and analyzed with spreadsheet (EXCEL-Microsoft Office Professional)*, graphing, and statistical software (SPSS and Statistica) on desktop computers.

An additional computer-based data acquisition system was also installed in the simulator to provide 16 additional input data channels to record physiological data from the aviator test subjects. This supplementary data acquisition system permitted continuous monitoring of test subject physiological responses to ensure compliance with core temperature and heart rate limits imposed by the USAARL Human Use Committee.

Four continuously recording video cameras and voice recorders were used to monitor the volunteer pilots when they were in the simulator. Research technicians were able to slew these cameras using a control device located in the rear area of the simulator cockpit. A forward-looking camera fixed to the top of the instrument

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* See list of manufacturers in Appendix J

glareshield allowed remote monitoring of the view out the left front window. The other cameras were oriented to provide close-up, uninterrupted, remote monitoring of the appearance and responsivity of the test subjects throughout the simulator sessions. The volunteer aviators were informed about the camera system and all provided written consent to be recorded and photographed during the study.

UH-60 automatic flight control system

Like the actual UH-60 Blackhawk helicopter, the USAARL UH-60 simulator is equipped with an automatic flight control system (AFCS) which enhances stability and handling qualities (Department of the Army, Technical Manual 1-1520-237-10). The AFCS has four subsystems: the stabilator, the stability augmentation system (SAS), the trim system, and flight path stabilization (FPS). The stabilator, a 14 foot by 4-inch variable angle-of-incidence airfoil, provides control in the pitch axis and a level attitude at a hover. The SAS enhances dynamic stability in all axes, thus preventing "porpoising" in the pitch axis, rolling in the roll axis and "fishtailing" in the yaw axis. The trim system consists of three trims for pitch, roll, and yaw axes. The trim function provides cyclic (pitch and roll) and pedal (yaw) flight control position reference and control gradient to maintain the cyclic stick and pedals at a desired position. To change or reset the pitch or roll trims, the pilot can:

a. Depress the cyclic trim release button, establish the new pitch or roll reference, and release the trim release button.

b. Move the trim switch (also on the cyclic) to establish the new pitch or roll reference.

c. Move the cyclic, then depress the trim release button or move the trim switch to neutralize the force on the cyclic.

Flight path stabilization is also provided for the pitch, roll and yaw axes. FPS provides very low frequency dampening (static stability). FPS functions maintain helicopter pitch attitude/airspeed hold, roll attitude hold, and heading hold and automatic turn coordination. FPS provides the following:

a. Pitch axis--attitude/airspeed hold.

b. Roll axis--bank angle/attitude hold.

c. Yaw axis, below 60 knots--heading hold.
Yaw axis, above 60 knots--heading hold and automatic turn coordination. (Maintains the aircraft in trim during a turn.)

During simulator flights in this study, the stabilator and SAS were always active. However, the trim system and FPS were deactivated for the 10-minute duration of every other set of standard maneuvers (starting with the second set). This degraded the AFCS thereby requiring more pilot control inputs and significantly increased pilot work load. For the sake of brevity, we henceforth refer to conditions where all components of the AFCS were on as "AFCS on" and conditions where the trim system and FPS components of the AFCS were off as "AFCS off."

UH-60 simulator flight profiles

Four simulator test sessions were conducted on 4 consecutive test days (Monday through Thursday). Each test session consisted of two flight profiles, or sorties, lasting approximately 2 hours each. These scenarios were representative of realistic UH-60 helicopter missions (USAAC,1989). A 10-minute simulated hot refueling break was provided between the two 2-hour sorties.

The first sortie was an air assault (AA) mission, which required the volunteer pilots to leave an airfield, fly to a landing zone (LZ), simulate off-loading an AA squad, fly away from the LZ on a designated flight path, return to the LZ, pick up the squad, and then return to the initial airfield (figure 2).

The second sortie was a medical evacuation (MEDEVAC) mission. This mission required the pilots to fly from a primary airfield to a secondary airfield, simulate the pickup of a MEDEVAC patient, and return to the initial airfield by a second route (figure 3).

During each sortie, the right seat pilot flew eight types of maneuvers as indicated by the mission scripts. Those maneuvers included: hover (HOV), hover turn (HOVT), right standard rate turn (RSRT), left descending turn (LDT), straight and level (SL), left climbing turn (LCT), contour, and nap-of-the-earth (NOE). Custom USAARL software automatically scored performance for the selected channels (e.g., airspeed, radar altitude, climb rate, turn rate, etc.).

Each sortie began at a simulated airfield. The first maneuver was a 1-minute 10-foot hover at a heading of 360° during which only radar altitude was scored. The next maneuver at the same location was a 1-minute 360° hover turn at 10 feet. Heading and radar altitude were scored during hover turns.

The crew then departed the airfield and proceeded to successive control points along the flight path, flying both contour and NOE as specified by the mission scripts (appendix A). Contour flying required the pilot to maintain 80 feet of radar altitude while NOE required the aircraft to be kept at 25 feet above the ground or highest obstacle

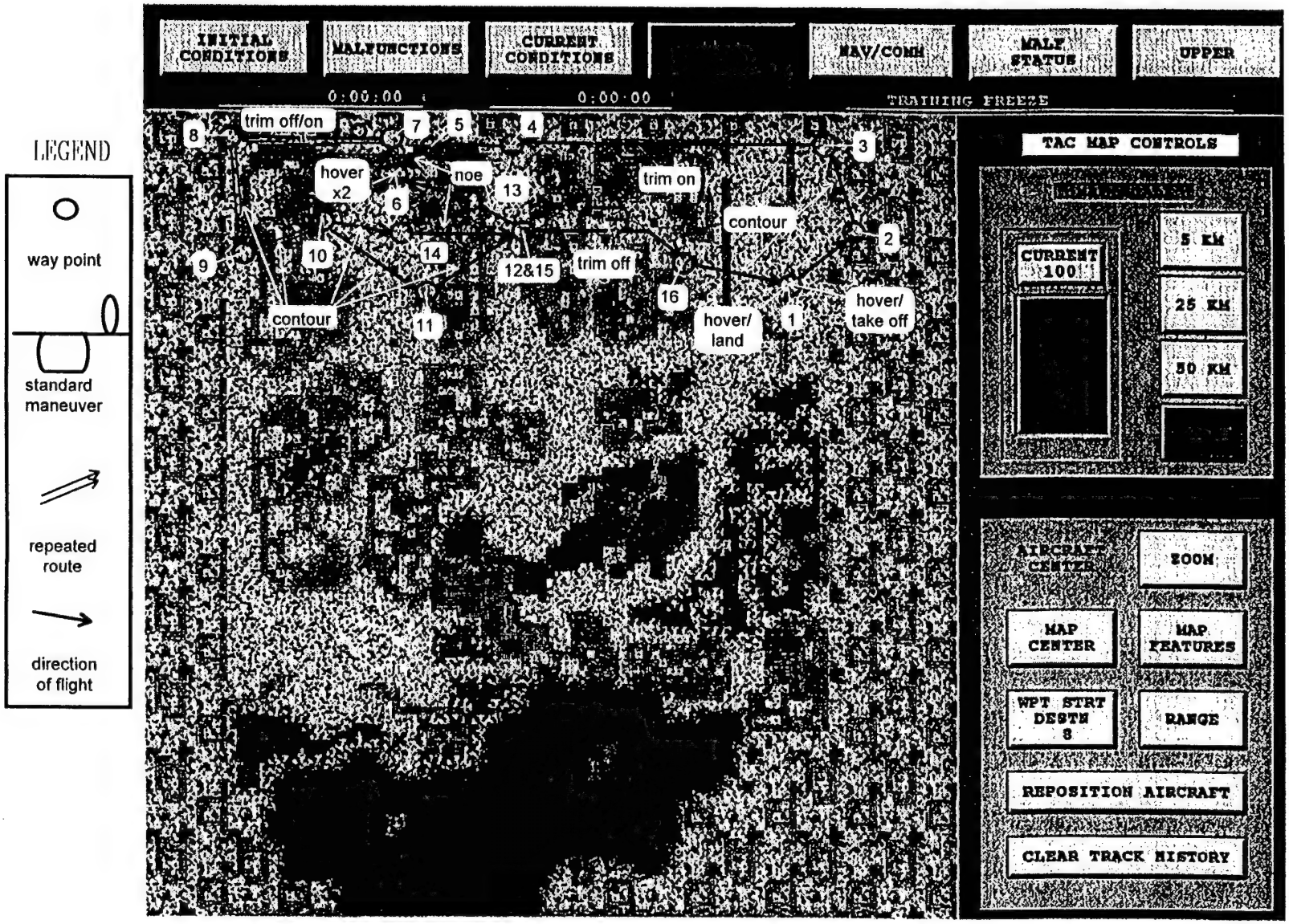


Figure 2. First 2-hour sortie: Air assault.

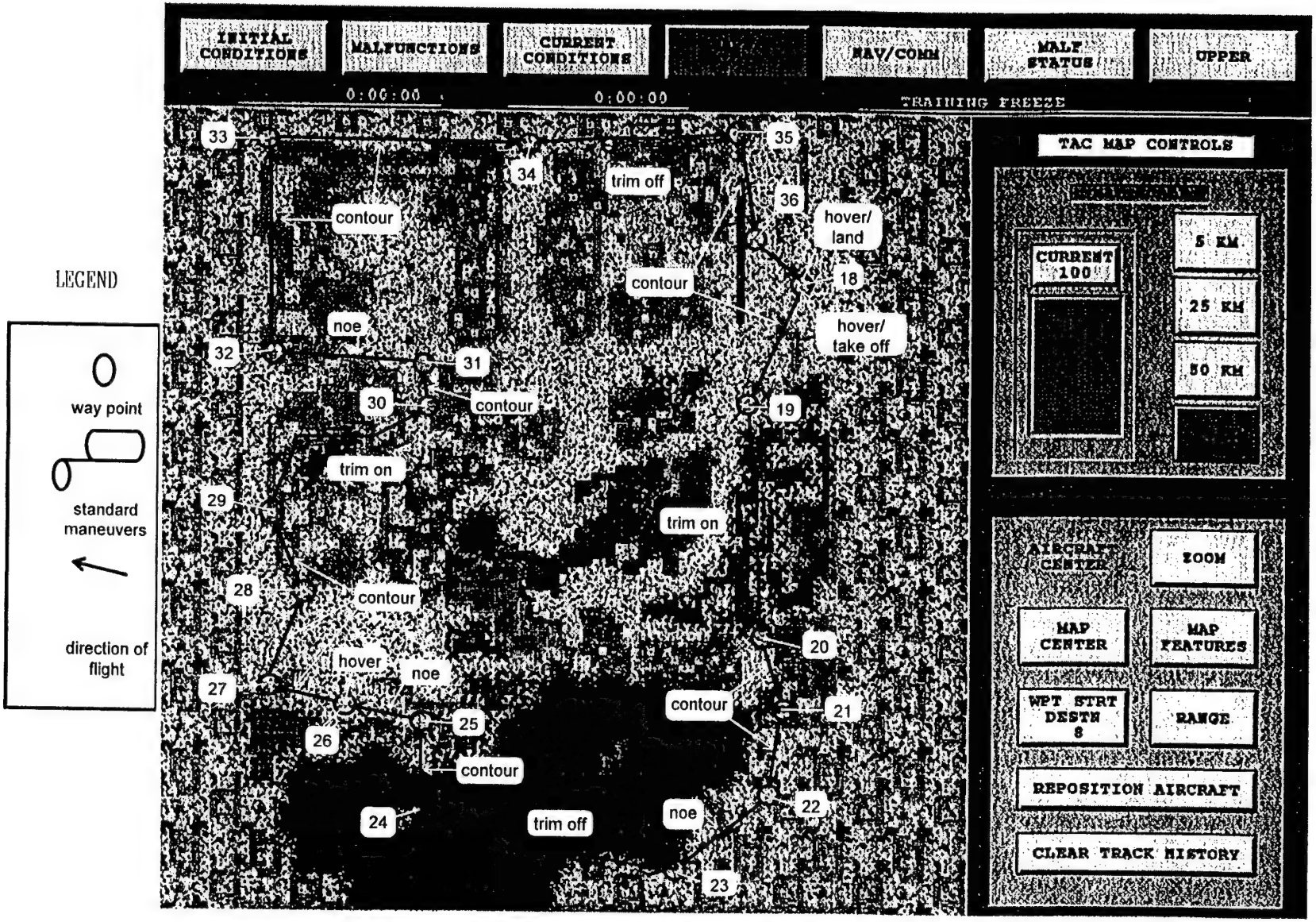


Figure 3. Second 2-hour sortie: MEDEVAC.

(eg., simulated trees). While flying in these modes, the pilots maintained heading determined by the direction to the next way point and flew at airspeeds sufficient to allow arrival at each control point within the desired time intervals. Heading, radar altitude, roll and slip were scored during NOE and contour flight modes.

During each of the two 2-hour sorties, the simulator operator caused a rapidly obscuring fog to develop every 30 minutes at the end of specific contour or NOE segments. This created instrument meteorological conditions (IMCs) to which the right seat pilot responded by ascending to 2000 feet at 500 feet per minute. On arrival at 2000 feet, the pilot commenced a 10-minute set of standard maneuvers composed of a sequence of four distinct maneuvers (SL, RSRT, LCT, and LDT). Eight sets of standard maneuvers were scheduled during each test session, four during the 2-hour AA sortie, and four during the 2-hour MEDEVAC sortie.

The first standard maneuver was SL at 2000 feet for 1 minute. This maneuver was scored on heading, indicated altitude, airspeed, roll and slip. An RSRT consisting of a 360° turn at a rate of 3° per second was then completed and scored on indicated altitude, airspeed, roll angle, and turn rate. Another 1-minute SL maneuver followed this and was scored the same as the first.

The pilot then performed an LCT with a 500 feet-per-minute rate of climb while turning 180° from the original heading at a rate of 3° per second. Scoring on this maneuver was on airspeed, climb rate, turn rate, and slip. A third 1-minute SL segment was completed and scored the same as the two previous SLs. The pilot then completed an LDT. This maneuver was performed and scored the same as the LCT. A final minute of SL flight completed the set of standard maneuvers. The pilot then descended out of IMC to resume visual flight rules (VFR) contour or NOE flight segments between designated way points according to the mission scripts.

During contour and NOE segments of each sortie (AA and MEDEVAC), the pilots were allowed to transfer flight control so that the right seat pilot could take an occasional break from flying, adjust uniform components or seat position to relieve pressure points, maintain hydration by drinking water from a standard issue canteen, and eat a small snack.

Multi-attribute test battery (MATB)

Every 30 minutes, as the right seat pilot encountered IMC conditions and began the ascent from contour or NOE level to 2000 feet indicated altitude to fly an iteration of the 10-minute set of standard maneuvers, the left seat pilot unstowed a laptop computer to simultaneously perform a 10-minute medium difficulty-level MATB*. Data from the MATB provided additional measures of the effects of aviator ensemble and environmental conditions on cognitive performance, tracking, situational awareness,

reaction times, and accuracy of responses to visual and auditory cues. An objective of including the MATB in the study was to determine the correlation between MATB results and the flight performance scores obtained during the corresponding simultaneously occurring set of standard flight maneuvers.

The MATB (figure 4) is a computer-based, aviation-related, synthetic task battery and performance assessment tool. It was initially developed by NASA researchers (Comstock and Arnegard, 1992) and is currently available from the Federal Aviation Administration's Civilian Aeromedical Research Institute (CAMI) in Oklahoma City, Oklahoma.

The MATB requires a test subject to simultaneously:

1. Detect changes in the condition of simulated warning lights and deviations of four strip gauges greater than ± 1 unit from midpoints and respond to changes by pressing the appropriate key on a computer keyboard.

2. Maintain cross hairs on a centrally fixed target with a joystick controller.

3. Detect the pilot's assigned call sign and message amid extraneous simulated radio traffic. The relevant messages require changing radio channels and frequencies. Simulated radio frequency changes are implemented by the test subject as accurately and quickly as possible via the computer keyboard.

4. Maintain simulated fuel levels in two primary fuel tanks at indicated levels by transferring fuel from four auxiliary fuel tanks interconnected by lines and fuel pumps.

A laptop computer and joystick were used to administer the MATB. Audio for the communications task was provided by patching the computer audio output into the cockpit's internal communication system. The volume was adjusted to a comfortable subjective level for the left seat pilot after donning the flight helmet at the beginning of each simulator session.

A printout of the baseline 10-minute, medium difficulty-level, MATB script is included in appendix F. In order to prevent the MATB pilots from becoming conditioned to, or excessively bored with an identical MATB script administered eight times per test session, the events in the baseline MATB script were randomized. Eight versions of the baseline 10-minute MATB event script were used, each of the same duration and difficulty level and with the same number and types of tasks but in randomly different order (within type of task, i.e., time intervals between events were identical for all the script files). The order of the eight script files was also randomized for each simulator session.

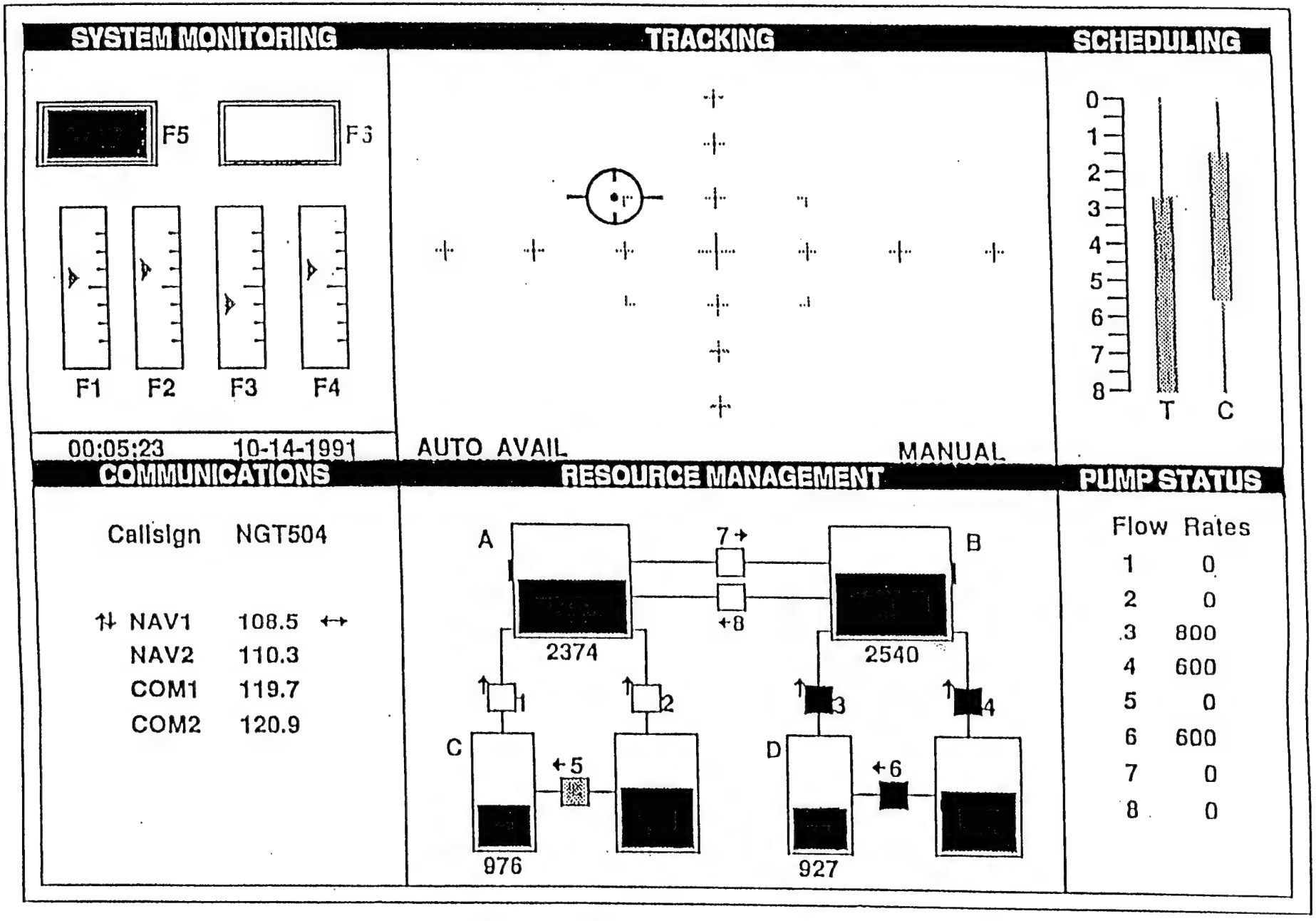


Figure 4. MATB display.

The following table enumerates the raw performance data automatically obtained by the MATB along with the calculated parameters for which statistics were obtained and analyzed for differences across iteration and test condition.

Table 3.
MATB performance data.

TASK	DATA FILE	STATISTICS FOR
Monitoring two warning lights and four strip gages and responding to warning light changes or out-of-range strip gage readings.	Elapsed time to 0.01 sec Code indicating an event requiring a response e.g.: red light on, green light off, gauges 1-4 out of desired range Response time to 0.01 sec	Response time Number of events Number of timed out events Number of false responses (i.e., false alarms)
Joystick target tracking	Elapsed time to 0.01 sec Level of tracking difficulty low, medium, high) Sum of squares pixel tracking error to 0.01 pixel Tracking error sampling rate RMS tracking error to 0.01pixel	RMS tracking error
Communications	Elapsed time to 0.01 sec Event code (own vs. other, call sign, and channel to switch to) Change of frequency	Time to respond to msg Accuracy of channel and frequency changes Missed messages Responses to others' messages
Fuel (resource) management	Elapsed time to 0.01 sec Pump activity (pump #, on-off, failure, repair) Fuel in tanks A, B, C, and D	RMS deviation from target fuel levels in tanks A & B Number of user initiated pump activities

Task load ratings

The NASA Task Load Index (TLX) questionnaire (appendix I), developed by the Human Performance Research Group at the NASA Ames Research Center (Hart and Staveland, 1988), was administered every 30 minutes to the right seat pilot at the completion of each 10-minute set of standard maneuvers and to the left seat pilot immediately after completing each 10-minute MATB performance test.

The TLX questionnaire requires subjective ratings, on a 0 to 20 Likert-type scale, for mental demand, physical demand, temporal demand, performance, effort, and frustration level. Mental demand is a subjective estimate of the mental and perceptual effort that was required to perform a task (0=none, 20=overwhelming). Physical demand is the difficulty of the physical activity and exertion required by a task (0=none to 20=impossibly difficult). Temporal demand is the pace of task requirements or degree of time pressure (0=none to 20=overwhelming). Performance is a rating regarding the extent to which task objectives and criteria were achieved (0=perfect to

20=failure). Effort is a rating of how hard the individual worked to achieve the measured level of performance (0=none to 20=maximum). And, frustration level is a rating of how annoyed, irritated, or angry the individual became in attempting to achieve target performance during the task (0=none to 20=maximum).

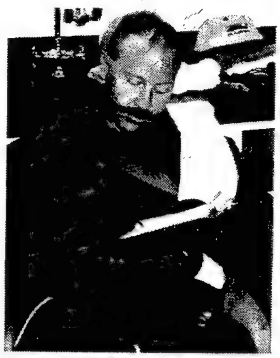
Sequence of events in the study

All the aviator volunteers received a detailed briefing regarding the study and were informed of their right to withdraw from participation, at their discretion, without any penalties. Prior to participation, the volunteer aviators read and signed the informed consent and were medically cleared for any evidence of significant illness or excess risk. Female participants were negative on a serum pregnancy test obtained as part of the medical evaluation. The aviator volunteers participated in the study for 2 consecutive weeks. The first week was for uniform and helmet fitting, simulator and MATB training, and heat stress acclimatization in the environmental chamber. During the second week (test week), the aviators completed four test sessions, one session per day for 4 consecutive days (Monday - Thursday).

During the first week, ambient conditions in the environmental chamber for acclimatization were 100°F and 20 percent RH. The volunteer aviators ambulated on treadmills in an environmentally controlled chamber. The treadmill speed was set at 3 mph and 0 percent grade for two 30-minute intervals separated by a 10-minute rest break. After the acclimatization sessions in the environmental chamber, the pilots had 2-hour training flights in the UH-60 flight simulator with ambient conditions in the cabin increased daily from 90°F and 50 percent RH to 100°F and 50 percent RH. These simulator sessions provided some additional acclimatization as well as familiarization with the two different flight missions, the MATB computerized performance test, and the questionnaires (appendix I).

During their second week, the test subjects arrived each day at approximately 0700 hours, self inserted a rectal thermistor*, were assisted with the application of skin temperature sensors and electrocardiogram (ECG) leads*, and then donned the designated flight uniform (figure 5). The volunteers then entered the environmental chamber where they walked on treadmills at a 3 mph pace and 0 percent grade for 20 minutes. Per Thornton et al (1992), this method was used to approximate the metabolic heat load generated during an actual UH-60 preflight inspection. After completing the 20-minute simulated preflight inspection, the crew walked a short distance to the USAARL UH-60 simulator. Core temperature and heart rate were monitored every 10 minutes to ensure adherence to physiological limits as approved in the research protocol (core temperature limit of 102.56°F, or 39.2°C, and heart rate not to exceed 90 percent of age adjusted predicted maximum). Pre- and posttest weights

Test subject instrumentation & prep room → Environmental chamber with 2 treadmills

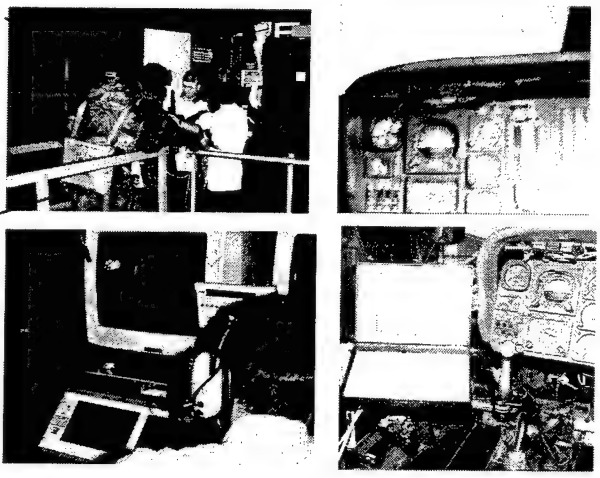


Instrumentation: core temp, heart rate sensors
Don flight uniform
Pretest: nude and clothed weights
POMS questionaire
Pretest canteen & all snack food weights
Initiate data recorders

Cool condition: 70°F, 20% RH
Hot condition: 100°F, 20%RH

Simulated preflight:
don flight helmet
20 min walk on treadmill
3 mph, 0 grade
Pre-, & post preflight mood & symptoms questionaire
Water ad libitum

UH-60 simulator
2 hrs: air assault scenario
10 min: simulated hot refuel break
2 hrs: MEDEVAC scenario



Disconnect from portable data recorders
Assist test subjects into the cockpit
Connect to physiological data aquisition system
Technician initializes MATB for left seat pilot
Sim operator initalizes HAWK flight performance system
Every 30 mins: 10 min set of standard maneuvers at 2-2.5 k alt
10 min med difficulty MATB
questionaires: mood & symptoms
task load index (TLX)
Every 10 mins : manual data recording:
core temp & heart rate
cockpit environmental conditions

Cool condition: 70°F, 50%RH
Hot condition: 100°F, 50%RH

Monitoring station

Post simulator cool-down room

Post session clothed weight
Cooling: fans, iced towels
Hydration: cooled water
Venous sample for catecholamines
Post session POMS questionaire

Remove sensors
Posttest nude weight
canteens & snack food weights
Final checks
Release for day

Figure 5. Heat stress study process.

and fluid intake and output were obtained to determine sweating rates and levels of dehydration.

Each simulator flight session during the test week consisted of two 2-hour sorties (AA and MEDEVAC, respectively) with an intervening 10-minute simulated hot refueling break. Every 30 minutes during the simulator session, the right seat pilot encountered IMC conditions and flew a 10-minute set of standard flight maneuvers. During the simulator flights, the data acquisition systems collected flight performance and physiological data. When subjective or objective indicators suggested that test subject tolerance limits were about to be reached, the volunteer pilots were instructed to make a simulated landing and both test pilots were assisted out of the simulator and escorted to a cooling and recovery room.

While the right seat pilot was flying the set of standard maneuvers, the left seat pilot was simultaneously using a stowable laptop computer and joystick to take the 10-minute, moderate difficulty-level, MATB performance test.

Results

In the tables and charts of results, reference to the unencumbered MOPP0 ABDU flight uniform is abbreviated as ABDU. Reference to the encumbered MOPP4 over ABDU ensemble is abbreviated as MOPP4. Likewise, the 70°F, 50 percent RH condition is abbreviated as the cool condition (although temperate might be technically more accurate) and the 100°F, 50 percent RH condition is abbreviated as the hot condition.

Repeated measures analysis of variance (ANOVA) was the primary hypothesis testing procedure utilized to determine whether means for performance variables and task load ratings were significantly different across the two levels of each of the two main factors (environmental temperature setting and type of flight uniform). For ease of interpretation, the ANOVA results tables typically list means for each variable across the test conditions and the resulting F and p statistics with degrees of freedom for effects and residual error. The customary $p \leq 0.05$ criteria served as the decision threshold for rejecting null hypotheses that differences in means were due exclusively to chance or random variation in uncontrolled and unmeasured factors.

Means and p-values in the ANOVA results tables are utilized together to determine the magnitude and direction of differences in mean responses for variables across the different levels of the two factors. Significance for only the environmental temperature factor indicates that differences in mean performance values or workload ratings were only associated with differences in environmental temperature, but not the different flight uniforms. Similarly, significance for a variable for only the uniform factor indicates

that differences in mean responses were only associated with type of uniform, but not with the different temperature conditions. Significance for interaction between temperature and uniform indicates that the slope of the response with respect to temperature differed for the two levels of uniform, or vice versa.

Test subjects

Twelve male and two female aviators between the ages of 27 and 50 (mean 35.6 years of age) completed participation in this study. No volunteer had an exclusionary medical condition. Each of the 14 completed at least 1 complete week of actual testing. Three test subjects volunteered for an additional test week. Therefore, there were 14 distinct test subjects but 17 test subject numbers.

Ten (71.4 percent) of the aviators were UH-60 rated; the remainder were rated in various other helicopters. Average total career flight time was 1453 (320-2800) hours with an average of 452 (0-1800) total hours flying UH-60s and an average of 69 (0-300) total hours in UH-60 simulators. There were 3 officers and 11 warrant officers. Four (28.6 percent) volunteers were from the Army National Guard, the remainder (77.4 percent) were from various active duty Army aviation units. Four of the volunteer pilots had previously participated in other USAARL studies.

Average height and weight for the volunteer aviators was 70 inches and 170 pounds, respectively. Performance results for their most recent Army physical fitness training (APFT) test included an average score of 261 (209-300), with an average of 55 pushups, 63 situps, and 17:52 for the 2-mile run. The average self-rated effort for their most recent APFT test was 92 percent of perceived maximum possible effort. These data indicated that the test subjects, as a group, were in good physical condition.

Average number of hours of CB training over the preceding 1 and 5 years were 0.64 (0-3) hour and 8 (0-52) hours, respectively. They also had an average of 1.28 (0-6) hours of heat illness prevention training over the preceding 2 years. For further demographic details, see appendix B.

Environmental conditions

Repeated measures ANOVA was performed on mean cockpit temperatures and humidity to determine how closely actual cockpit environmental conditions during the test sessions were to those specified in the study design. Results showed that there were no statistically significant differences between actual and specified values for either of the temperature and humidity settings (70°F, 50 percent RH and 100°F, 50 percent RH) across the two different flight uniforms (ABDU and air warrior). These results verified excellent control of the environmental conditions during the study (see

Reardon et al, 1996 for further detail). Cockpit WBGT for the cool condition was 70°F (21.1°C) and for the hot condition, 90°F (32.2°C).

Endurance

All the volunteer pilots were able to complete the full 4-hour two-sortie mission (nominally 300 minutes in duration) for each of the test conditions except the encumbered MOPP4-hot condition. None of the aviators or crew were able to complete even the first 2-hour sortie in the MOPP4-hot condition. Overall, crew endurance was reduced ($p<<0.05$) by 65 percent, from an average of 309 minutes for the cool and ABDU conditions, to only 107 minutes (figure 6) for the encumbered MOPP4-hot condition. The reasons for this were the much greater physiological and psychological heat strain caused by the encumbered MOPP4-hot condition (see detailed physiological results in Reardon, et al., 1996). For seven of the nine crews, duration in the MOPP4-hot condition was limited by at least one of the pilots reaching the safety limit for core temperature (39.2°C or 102.56°F). Even so, the crews on exiting the simulator typically manifested signs of mild to moderate heat exhaustion. A few also had several minutes of orthostatic lightheadedness. (All recovered uneventfully to their pretest baseline conditions after 30-60 minutes of rest, fluids, and cooling with a fan and iced towels).

There were no significant correlations between endurance in the MOPP4-hot condition and aviator characteristics. Cross correlations between endurance and age (0.1339), height (-0.2124), weight (-0.2530), recent APFT score (0.3875), career flight hours (-0.3594), career UH-60 hours (0.2163), career simulator hours (0.3969), and amount of recent heat stress training (-0.3330) were relatively small and not statistically different from zero.

Flight performance results

The charts and repeated measures ANOVA tables in appendix C summarize flight performance results. The right seat pilots alternated use of the AFCS for each iteration of the set of standard maneuvers (SL, RSRT, SL, LCT, SL, LDT, SL) as specified in the flight scripts. Hovers, hover turns, and NOE and contour segments, however, were always flown with the AFCS on.

Flight performance scores, indicating how well the pilots maintained target values for each parameter during each maneuver, as specified in the flight profile scripts (appendix A), were calculated in two steps. First, mean scores for each of the relevant parameters associated with each maneuver were automatically calculated using the scoring bands in table 4. Second, the scores from each of the graded parameters were averaged into a single composite score for each maneuver.

Figure 6.
Aviator Endurance.

(Time in uniform-in minutes)
From beginning of treadmill session to end of simulator flight

TS NUMBER	ABDU+70F	ABDU+100F	MOPP4+70F	MOPP4+100F
1	319.00	307.00	314.00	120.00
2	319.00	307.00	314.00	120.00
3	310.00	305.00	322.00	98.00
4	310.00	305.00	322.00	98.00
5	347.00	319.00	302.00	140.00
6	338.00	333.00	323.00	92.00
7	338.00	333.00	323.00	92.00
8	292.00	299.00	288.00	92.00
9	292.00	299.00	288.00	92.00
10	301.00	301.00	330.00	91.00
11	301.00	301.00	330.00	40.00
12	296.00	292.00	302.00	97.00
13	296.00	292.00	302.00	148.00
14	289.00	296.00	302.00	99.00
15	289.00	296.00	302.00	99.00
16	308.00	310.00	322.00	152.00
17	308.00	310.00	322.00	152.00
AVERAGE	309.00	306.18	312.24	107.18
2*SE	8.72	5.94	6.59	13.93
Max	347.00	333.00	330.00	152.00
Min	289.00	292.00	288.00	40.00

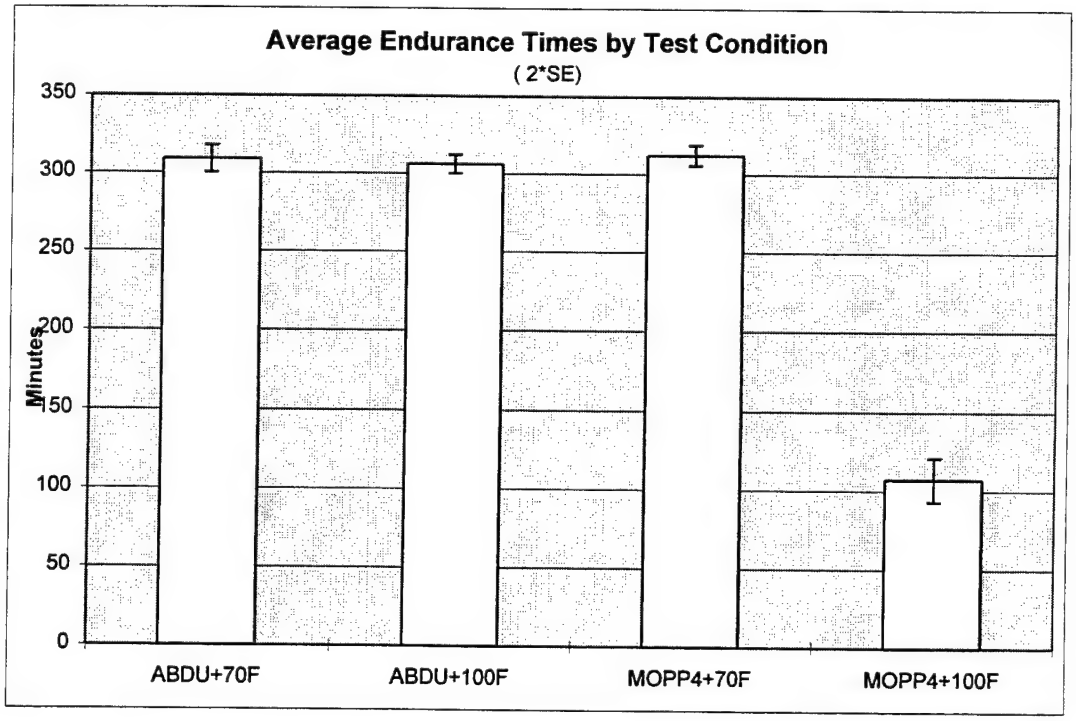


Table 4.

Scoring bands for flight performance deviations from target values.

	Maximum deviations from performance standards for scores of:					
Measure (units) \ Score	100	80	60	40	20	0
Heading (degrees)	<0.5	1.0	2.0	4.0	8.0	> 16.0
Altitude (feet)	<4.4	8.8	17.5	35.0	70.0	>140.0
Airspeed (knots)	<0.65	1.3	2.5	5.0	10.0	> 20.0
Slip (ball widths)	<0.025	0.0	0.1	0.2	0.4	> 0.8
Roll (degrees)	<0.4	0.8	1.5	3.0	6.0	> 12.0
Vert. Speed (feet/m)	<5.0	10.0	20.0	40.0	80.0	>160.0
Turn Rate (degrees/s)	<0.15	0.3	0.5	1.0	2.0	> 4.0

Table 5 provides reference values utilized in scoring flight performance for the specific data channels selected for each type of maneuver. *Best* are the target values associated with 100 percent performance score. *High* are deviations from the target values beyond which subjects would receive a score of zero. *Wgt* are weightings for a weighted average composite score (ACS). *ATM* are the maximum deviations from the target values permitted by aircrew training manual standards (Department of the Army, 1996).

Table 5.

Flight performance standards by data channel and maneuver.

LEFT CLIMBING TURN	5, Data Channels					
Data Channel Description	## Channel	Abrev.	Best	High	Wgt	ATM
Climb rate (ft/min)	01 FROC	Cli	500	160	1	100
Turn rate (deg/sec)	02 FDPSID	Trn	-3	4	1	
Pilot indicated airspeed (knots)	03 FIASR	Asp	120	20	1	10
Roll angle (degrees)	04 FPHID	Rol	-19	12	1	10
Slip ball position (n-d)	05 FSLIPP	Slp	0	0.8	1	

STRAIGHT & LEVEL	5, Data channels					
Data Channel Description	## Channel	Abrev.	Best	High	Wgt	ATM
Heading (degrees)	01 UDISHG	Hdg	150	16	1	10
Indicated altitude (feet)	02 FALTI	Alt	2000	140	1	100
Pilot indicated airspeed (knots)	03 FIASR	Asp	120	20	1	10
Roll angle (degrees)	04 FPHID	Rol	0	12	1	10
Slip ball position (n-d)	05 FSLIPP	Slp	0	0.8	1	1

LEFT DESCENDING TURN	5, Data Channels					
Data Channel Description	## Channel	Abrev.	Best	High	Wgt	ATM
Climb rate (ft/min)	01 FROC	Cli	-500	160	1	100
Turn rate (deg/sec)	02 FDPSID	Trn	-3	4	1	
Pilot indicated airspeed (knots)	03 FIASR	Asp	120	20	1	10
Roll angle (degrees)	04 FPHID	Rol	-19	12	1	10
Slip ball position (n-d)	05 FSLIPP	Slp	0	0.8	1	1

Table 5. (continued)

HOVER — 2, Data Channels

Data Channel Description	## Channel	Abrev.	Best	High	Wgt	ATM
Radar altitude (feet)	01 URDALT	Alt	40	16	1	3
Heading (degrees)	02 UDISHG	Hdg	20	8	1	10

HOVER TURN — 1, Data Channels

Data Channel Description	## Channel	Abrev.	Best	High	Wgt	ATM
Radar altitude (feet)	01 URDALT	Alt	40	16	1	3

RIGHT STANDARD RATE TURN — 5, Data Channels

Data Channel Description	## Channel	Abrev.	Best	High	Wgt	ATM
Turn rate (deg/sec)	01 FDPSID	Trn	3	4	1	
Indicated altitude (feet)	02 FALTI	Alt	2000	140	1	100
Pilot indicated airspeed (knots)	03 FIASR	Asp	120	20	1	10
Roll angle (degrees)	04 FPHID	Rol	20	12	1	10
Slip ball position (n-d)	05 FSLIPP	Slp	0	0.8	1	1

CONTOUR — 4, Data Channels

Data Channel Description	## Channel	Abrev.	Best	High	Wgt	ATM
Radar altitude (feet)	01 URDALT	Ral	80	80	1	100
Heading Error (degrees, COMPUTED)	02 *V07	HdE	0	10	1	10
Roll angle (degrees)	03 FPHID	Rol	0	12	1	10
Slip ball position (n-d)	04 FSLIPP	Slp	0	0.8	1	1

NAP OF THE EARTH — 4, Data Channels

Data Channel Description	## Channel	Abrev.	Best	High	Wgt	ATM
Radar altitude (feet)	01 URDALT	Ral	25	25	1	100
Heading Error (degrees, COMPUTED)	02 *V07	HdE	0	10	1	10
Roll angle (degrees)	03 FPHID	Rol	0	12	1	10
Slip ball position (n-d)	04 FSLIPP	Slp	0	0.8	1	1

Average composite scores

Average composite flight performance scores at each sampling point during an iteration of a particular type of maneuver were calculated as an unweighted average of the individual scores for the maneuver-specific flight performance data channels. These sample-point ACSs were then averaged across each iteration. Lastly, the iteration ACSs were averaged to obtain an average ACS for each pilot by type of maneuver and test condition.

There were insufficient degrees of freedom to perform a multiple analysis of variance (MANOVA) to evaluate the overall effects of the main factors, temperature and type of uniform on the ACSs for all the maneuvers taken together. Alternatively, a three-way (temperature, uniform, and type of maneuver) repeated measures ANOVA was performed on the average composite flight performance scores (table 6). These results

indicated a significant first-order interaction of cockpit temperature and type of flight uniform on flight performance, as well as a significant main effect for type of uniform.

Table 6.

Three-way repeated measures ANOVA for flight performance: ACS scores.

	df Effect	MS Effect	df Error	MS Error	F	p-level
Temperature	1	46.14	6	14.53	3.18	0.13
Uniform	1	336.40	6	35.27	9.54	**0.02**
Maneuver	7	5235.68	42	33.57	155.96	**0.00**
Temperature and Uniform	1	231.88	6	19.84	11.69	**0.01**
Temperature and Maneuver	7	19.44	42	18.37	1.06	0.41
Uniform and Maneuver	7	18.75	42	21.11	0.89	0.52
Temperature, Uniform, and Maneuver	7	8.49	42	19.70	0.43	0.88

Repeated measures ANOVA (table 7a,b) was also used to determine the specific flight parameters for each type of maneuver exhibiting significant main factor and interaction effects. Analysis was performed separately for data from the maneuvers where the AFCS was on, off, and both on and off. The last was justified on the basis that during actual UH-60 flight, pilots frequently switch the AFCS off for short periods to either align the aircraft for a new AFCS flight track, or for the benefits of close manual control during demanding flight conditions.

When flight performance was averaged across AFCS on and off for all iterations of each maneuver, the encumbered MOPP4 uniform was associated with significantly reduced ACS for five (HOV, HOVT, RSRT, SL, and contour) of eight (62.5 percent) maneuvers (table 8). In addition to the effects on the composite scores, 5 of the 29 (17.2 percent) separately scored flight parameters for the 8 maneuvers were significantly reduced (table 11). For the averaged AFCS on and off results, the hot temperature condition by itself, as a main effect, reduced the ACS for only one (RSRT) of eight maneuvers (table 7a,b).

For the iterations of the maneuvers flown with AFCS on, the MOPP4 ensemble was associated with significantly lower ACS for three (HOV, HOVT, and contour) of the eight (37.5 percent) types of maneuvers compared to the ABDU conditions (table 7a,b). The Air Warrior ensemble did not significantly reduce performance scores for the standard maneuvers when flown with trim on. In addition to the effects on the composite scores, 5 of the 29 (17.2 percent) separately scored flight parameter scores for the 8 maneuvers were significantly reduced. For the averaged AFCS on results, the

Table 7a.

Repeated measures ANOVA results for flight performance scores.

REPEATED MEASURES ANOVA RESULTS FOR FLIGHT PERFORMANCE SCORES - TRIM ON and OFF													
MEAN SIMULATOR FLIGHT PERFORMANCE SCORES BY MANEUVER							MAIN EFFECTS				INTERACTION	
							TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
HOV	ACS	9	78.43	74.81	79.05	72.85	0.21	0.6587	10.51	**0.0119**	0.86	0.3797
	HEADING	9	69.56	66.36	71.48	69.91	1.85	0.2112	1.21	0.3029	0.22	0.6481
	RADAR ALT	9	87.33	83.29	86.52	75.43	6.59	**0.0333**	16.93	**0.0034**	2.67	0.1409
HOVT	ACS	9	43.44	41.00	43.83	40.19	0.05	0.8299	6.15	**0.0381**	0.59	0.4662
	RADAR ALT	9	86.33	81.35	87.10	80.04	0.02	0.8918	5.65	**0.0448**	0.44	0.5243
	TURN RATE	9	0.46	0.48	0.49	0.44	0.00	1.0000	0.03	0.8602	0.06	0.8176
RSRT	ACS	9	71.36	70.91	72.42	65.27	14.86	**0.0062**	15.86	**0.0053**	8.71	**0.0214**
	INDICATED ALT	9	66.97	66.20	67.30	57.46	2.94	0.1303	9.60	**0.0173**	2.29	0.1738
	AIR SPEED	9	83.27	82.33	84.67	79.43	0.80	0.4003	19.87	**0.0020**	3.59	0.1000
	ROLL ANGLE	9	79.02	79.19	77.25	72.38	7.79	**0.0269**	3.20	0.1169	1.43	0.2706
	TURN RATE	9	87.05	85.94	86.95	81.41	4.76	0.0655	11.95	**0.0108**	3.86	0.0903
LCT	ACS	9	50.59	50.58	51.17	48.00	1.58	0.2488	3.61	0.0993	3.17	0.1183
	AIR SPEED	9	73.30	73.25	74.05	68.72	0.88	0.3765	1.38	0.2779	12.98	**0.0087**
	SLIP	9	15.25	14.72	16.58	16.65	1.63	0.2422	0.08	0.7793	0.14	0.7149
	CLIMB RATE	9	23.59	24.28	24.88	19.75	1.11	0.3261	2.68	0.1456	4.54	0.0706
	TURN RATE	9	76.59	76.59	76.59	73.83	0.67	0.4391	2.05	0.1949	0.88	0.3783
SL	ACS	9	70.67	68.77	72.14	65.06	0.70	0.4312	9.56	**0.0175**	6.28	**0.0407**
	HEADING	9	85.72	83.52	85.39	78.47	4.23	0.0787	6.30	**0.0404**	2.56	0.1535
	INDICATED ALT	9	62.75	58.70	65.25	54.85	0.06	0.8156	2.50	0.1575	0.67	0.4415
	AIR SPEED	9	81.00	79.91	81.83	74.75	3.47	0.1048	22.26	**0.0022**	1.83	0.2179
	ROLL	9	78.67	80.11	79.78	73.82	2.38	0.1670	2.66	0.1466	22.07	**0.0022**
	SLIP	9	45.28	41.91	48.50	43.27	0.62	0.3943	1.35	0.2839	0.08	0.7816
LDT	ACS	9	53.70	53.36	54.36	50.30	0.83	0.3937	2.14	0.1866	1.84	0.2170
	AIR SPEED	9	78.72	75.22	76.41	72.59	1.82	0.2190	2.34	0.1696	0.00	0.9552
	SLIP	9	27.27	26.98	29.70	28.73	0.34	0.5805	0.05	0.8322	0.59	0.4667
	CLIMB RATE	9	26.09	24.66	25.23	20.07	3.17	0.1182	2.32	0.1714	1.42	0.2727
	TURN RATE	9	74.00	74.66	75.84	70.80	0.63	0.4519	1.04	0.3415	5.06	0.0593
NOE	ACS	9	46.18	45.97	47.24	44.27	0.12	0.7425	1.49	0.2565	3.02	**0.1206**
	HEADING	9	55.37	54.89	57.90	54.52	0.48	0.5071	0.90	0.3706	1.40	0.2705
	RADAR ALT	9	26.94	25.33	27.75	15.01	4.57	0.0651	5.40	**0.0487**	10.45	**0.0120**
	ROLL	9	64.34	65.88	64.14	66.96	0.11	0.7472	2.10	0.1853	0.10	0.7584
	SLIP	9	36.40	37.75	39.01	40.33	0.32	0.5849	0.03	0.8774	0.25	0.6277
CONTOUR	ACS	9	57.90	56.49	59.54	54.38	0.09	0.7728	11.43	**0.0096**	4.52	0.0661
	HEADING	9	63.38	61.04	65.17	58.49	0.04	0.8493	7.43	**0.0240**	2.04	0.1906
	RADAR ALT	9	50.58	49.83	52.68	45.00	0.69	0.4316	4.73	0.0614	3.42	0.1018
	ROLL	9	76.78	75.93	77.46	74.68	0.12	0.7432	7.07	**0.0289**	0.82	0.3928
	SLIP	9	40.54	39.15	42.72	39.44	0.23	0.6425	2.26	0.1712	0.23	0.6477

Table 7b.

Repeated measures ANOVA results for flight performance scores.

REPEATED MEASURES ANOVA RESULTS FOR FLIGHT PERFORMANCE SCORES - TRIM OFF

MEAN SIMULATOR FLIGHT PERFORMANCE SCORES BY MANEUVER							MAIN EFFECTS: TEMPERATURE		MAIN EFFECTS: UNIFORM		INTERACTION: TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
RSRT	ACS	9	66.81	66.75	67.38	58.63	10.11	0.0158	4.22	0.0791	3.87	0.0696
	INDICATED ALT	9	62.53	60.75	62.06	50.56	4.73	0.0661	3.37	0.1081	1.81	0.2208
	TURN RATE	9	83.44	83.63	81.06	78.13	4.90	0.0624	0.77	0.4067	0.78	0.4056
	AIR SPEED	9	78.81	77.56	79.06	71.75	4.26	0.0780	11.45	0.0117	5.43	0.0526
	ROLL ANGLE	9	70.92	71.78	67.63	67.86	3.85	0.0654	0.10	0.7632	0.01	0.9057
LCT	ACS	9	45.56	44.86	45.38	40.25	12.72	0.0091	5.03	0.0598	2.26	0.1781
	AIR SPEED	9	70.63	69.03	69.56	59.81	2.34	0.1700	2.18	0.1848	1.95	0.2055
	SLIP	9	8.06	8.19	8.13	7.88	1.04	0.3413	0.00	0.9727	0.01	0.9130
	CLIMB RATE	9	16.50	15.94	16.44	11.75	8.33	0.0401	6.64	0.0506	4.23	0.0767
	TURN RATE	9	72.28	71.25	71.19	67.81	1.84	0.2081	1.37	0.2797	0.18	0.6856
SL	ACS	9	64.59	61.41	66.25	57.69	0.23	0.6471	12.77	0.0066	1.45	0.2672
	HEADING	9	84.38	80.63	84.94	75.75	2.95	0.1298	19.70	0.0030	1.95	0.2049
	INDICATED ALT	9	57.22	50.16	60.00	53.44	1.48	0.2665	2.65	0.1458	0.00	0.9472
	AIR SPEED	9	75.94	76.47	77.09	71.25	1.42	0.2717	1.81	0.2455	0.69	0.4345
	ROLL	9	71.66	72.25	71.78	62.63	4.94	0.0617	3.76	0.0928	4.80	0.0645
	SLP	9	33.78	28.03	37.28	25.69	0.01	0.9252	3.90	0.0655	0.66	0.4428
LDT	ACS	9	46.84	44.94	47.06	39.44	3.46	0.1052	15.06	0.0046	2.31	0.1727
	AIR SPEED	9	74.13	67.72	71.56	61.50	4.78	0.0655	8.11	0.0427	0.29	0.6098
	TURN RATE	9	70.50	68.56	70.72	61.25	3.00	0.1271	3.63	0.0963	2.03	0.1989
	CLIMB RATE	9	19.63	16.88	19.84	10.81	11.55	0.0118	17.75	0.0040	2.32	0.1718
	SLP	9	10.13	13.34	12.91	12.69	0.36	0.5682	0.21	0.6641	0.86	0.3856

REPEATED MEASURES ANOVA RESULTS FOR FLIGHT PERFORMANCE SCORES - TRIM ON

MEAN SIMULATOR FLIGHT PERFORMANCE SCORES BY MANEUVER							MAIN EFFECTS: TEMPERATURE		MAIN EFFECTS: UNIFORM		INTERACTION: TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
HOV	ACS	9	76.43	74.81	79.05	72.85	0.21	0.6567	10.51	0.0118	0.86	0.3797
	HEADING	9	89.56	86.38	71.48	89.91	1.85	0.2112	1.21	0.3029	0.22	0.6481
	RADAR ALT	9	87.33	83.29	86.52	75.43	6.59	0.0333	18.93	0.0014	2.87	0.1409
HOVT	ACS	9	43.44	41.00	43.83	40.19	0.05	0.8299	8.15	0.0181	0.58	0.4662
	RADAR ALT	9	86.33	81.35	87.10	80.04	0.02	0.8918	5.65	0.0448	0.44	0.5243
	TURN RATE	9	0.46	0.48	0.49	0.44	0.00	1.0000	0.03	0.8602	0.06	0.8176
RSRT	ACS	9	75.91	75.06	76.06	70.81	8.00	0.2163	3.83	0.0912	2.89	0.1450
	INDICATED ALT	9	71.41	71.66	69.78	68.38	0.28	0.6120	0.03	0.8768	0.04	0.8476
	AIR SPEED	9	86.72	87.09	88.69	86.75	0.18	0.7001	0.26	0.6261	0.24	0.6373
	ROLL ANGLE	9	86.22	85.09	83.88	77.81	4.73	0.0662	1.60	0.2457	1.40	0.2748
	TURN RATE	9	90.66	88.25	89.72	84.69	1.33	0.2866	5.21	0.0505	1.40	0.2748
LCT	ACS	9	55.83	56.28	56.97	55.13	0.00	0.9524	0.17	0.6944	0.63	0.4546
	AIR SPEED	9	75.97	77.47	78.53	77.63	0.76	0.4117	0.02	0.8928	0.29	0.6238
	CLIMB RATE	9	28.69	30.75	31.31	27.00	0.04	0.8471	0.18	0.6961	2.31	0.1723
	TURN RATE	9	80.91	81.47	82.00	79.25	0.04	0.8474	0.55	0.4806	0.48	0.5069
	SLP	9	24.44	23.25	25.03	23.94	0.98	0.3290	2.94	3.5355	3.89	0.0648
SL	ACS	9	76.75	76.13	76.03	71.75	0.47	0.5159	2.65	0.1477	2.03	0.1972
	HEADING	9	87.06	86.41	85.84	81.25	1.21	0.3066	0.86	0.3841	0.54	0.4671
	INDICATED ALT	9	68.28	67.25	70.50	56.75	0.91	0.3708	2.08	0.1940	1.09	0.3315
	AIR SPEED	9	86.06	83.34	86.56	78.44	72.81	0.5333	48.91	4.8078	89.34	0.8543
	ROLL	9	85.47	87.97	87.56	83.25	0.37	0.5627	0.30	0.8028	3.56	0.1002
	SLP	9	56.78	55.78	59.72	58.44	1.02	0.3452	0.06	0.8119	0.00	0.9752
LDT	ACS	9	60.56	61.78	61.86	60.19	0.01	0.9113	0.00	0.9571	0.39	0.5513
	AIR SPEED	9	83.31	82.72	81.25	86.13	0.05	0.8270	1.00	0.3511	0.80	0.4029
	TURN RATE	9	77.50	80.75	80.97	78.50	0.43	0.5316	0.22	0.6527	0.85	0.4490
	CLIMB RATE	9	32.56	32.84	30.63	29.06	0.80	0.4017	0.03	0.8566	0.18	0.6874
	SLP	9	44.41	44.63	46.50	43.13	60.99	0.0087	57.89	0.3442	47.54	0.5433
NOE	ACS	9	46.18	45.97	47.24	44.27	0.12	0.7425	1.49	0.2565	3.02	0.1298
	HEADING	9	55.37	54.89	57.90	54.52	0.48	0.5071	0.90	0.3706	1.40	0.2705
	RADAR ALT	9	28.94	25.33	27.75	15.01	4.57	0.0651	5.40	0.0487	10.45	0.0126
	ROLL	9	64.34	65.88	64.14	66.98	0.11	0.7472	2.10	0.1853	0.10	0.7564
	SLIP	9	38.40	37.75	39.01	40.33	0.32	0.5849	0.03	0.8774	0.25	0.6277
CONTOUR	ACS	9	57.90	58.49	58.54	54.38	0.0692	0.7728	11.43	0.0096	4.52	0.0661
	HEADING	9	64.03	61.04	65.17	58.49	0.12	0.7358	7.51	0.0256	1.37	0.2762
	RADAR ALT	9	50.58	49.83	52.68	45.00	0.89	0.4318	4.73	0.0614	3.42	0.1016
	ROLL	9	76.78	75.93	77.46	74.58	0.12	0.7432	7.07	0.0289	0.82	0.3928
	SLIP	9	40.54	39.15	42.72	39.44	0.23	0.6425	2.26	0.1712	0.23	0.6477

hot temperature condition, as a main effect, did not reduce the ACS for any of the eight flight maneuvers (table 7a,b).

With AFCS off, the encumbered MOPP4 uniform significantly degraded the ACS for two (SL and LDT) (50 percent) of the four types of maneuvers in the set of standard maneuvers (table 8). In addition to the effects on the composite scores, 5 of the 17 (29.4 percent) separately scored flight parameters for the 4 maneuvers were significantly reduced (table 7a,b). For the averaged AFCS off results, the hot temperature condition, as a main effect, reduced the ACS for two (RSRT and LCT) of the four flight maneuvers that were alternately flown with AFCS off.

Table 8.
Effects of encumbered MOPP4 ensemble in hot conditions on average composite flight scores.

Maneuver	AFCS (trim) on & off	AFCS on	AFCS off
HOV	↓	↓	n/a
HOVT	↓	↓	n/a
RSRT	↓	↔	↔
LDT	↔	↔	↓
SL	↓	↔	↓
LCT	↔	↔	↔
Contour	↓	↓	n/a
NOE	↔	↔	n/a

* ↓ - indicates a significant decrease in average composite scores.
↔ - indicates no significant increase or decrease.

Root mean squared errors (RMSEs)

RMSEs were calculated as the square-root of the mean-squared deviations of the actual flight performance data from the corresponding target values for each data channel across all the sample points in an iteration of a maneuver. The RMSEs were then averaged across iterations to obtain an average RMSE for each type of maneuver and test condition.

Table 9a.

Repeated measures ANOVA results for flight performance RMSE.

REPEATED MEASURES ANOVA RESULTS FOR FLIGHT PERFORMANCE RMSE - TRIM ON and OFF												
RMSE FOR FLIGHT PARAMETERS BY MANEUVER							MAIN EFFECTS				INTERACTION	
							TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE(1,7)	P VALUE	F VALUE(1,7)	P VALUE	F VALUE(1,7)	P VALUE
HOV	HEADING ERR	9	1.68	1.83	1.43	1.67	2.89	0.1276	3.74	0.0893	0.15	0.7106
	RADAR ALT	9	1.46	2.03	1.40	2.72	3.27	0.1084	34.06	0.0001	3.83	0.0862
HOVT	RADAR ALT	9	1.49	1.92	1.41	1.91	0.06	0.8161	5.70	0.0440	0.07	0.7941
	TURN RATE	9	9.24	9.43	9.37	9.98	5.27	0.0507	5.75	0.0433	2.75	0.1361
RSRT	INDICATED ALT	9	32.17	34.70	35.80	59.72	5.03	0.0599	3.38	0.1087	1.86	0.2147
	AIR SPEED	9	2.31	2.31	2.27	2.85	1.83	0.2185	2.64	0.1484	2.20	0.1820
	ROLL ANGLE	9	3.45	3.41	3.70	4.59	5.52	0.0511	2.12	0.1885	1.52	0.2576
	TURN RATE	9	0.52	0.53	0.64	0.77	4.37	0.0750	0.46	0.5184	0.45	0.5248
LCT	AIR SPEED	9	3.41	3.44	3.20	4.32	1.04	0.3422	1.64	0.2412	4.48	0.0720
	SLIP	9	1.00	1.14	0.98	1.14	0.02	0.8819	8.27	0.0238	0.00	0.9527
	CLIMB RATE	9	251.58	246.98	234.87	290.19	0.88	0.3785	4.93	0.0619	4.41	0.0739
	TURN RATE	9	1.00	1.00	1.03	1.09	1.65	0.2402	3.50	0.1036	1.17	0.3159
SL	HEADING ERR	9	1.67	1.83	1.63	2.32	1.67	0.2375	4.86	0.0632	1.97	0.2034
	INDICATED ALT	9	40.64	44.38	34.81	55.19	0.33	0.5827	2.36	0.1686	1.47	0.2652
	AIR SPEED	9	2.39	2.73	2.42	3.44	7.30	0.0306	16.60	0.0047	0.78	0.4060
	ROLL	9	2.02	2.05	2.06	2.56	2.64	0.1480	3.10	0.1217	3.20	0.1170
	SLIP	9	0.34	0.52	0.30	0.63	0.22	0.6548	13.26	0.0083	1.05	0.3389
LDT	AIR SPEED	9	2.80	3.34	2.86	4.18	2.79	0.1386	6.42	0.0390	0.88	0.3791
	SLIP	9	0.75	0.72	0.75	0.93	1.49	0.2623	0.40	0.5459	1.49	0.2623
	CLIMB RATE	9	233.28	256.00	232.86	310.89	2.26	0.1766	12.83	0.0090	1.89	0.2113
	TURN RATE	9	1.20	1.09	1.02	1.06	2.10	0.1902	0.13	0.7245	6.48	0.0383
NOE	HEADING ERR	9	5.33	5.60	4.15	5.29	1.22	0.3010	1.38	0.2735	0.31	0.5921
	RADAR ALT	9	38.78	41.08	39.42	53.29	2.05	0.1897	1.46	0.2607	2.24	0.1732
	ROLL	9	4.88	4.61	4.81	5.01	0.16	0.6984	0.00	0.9487	0.14	0.7174
	SLIP	9	0.72	0.71	0.71	0.67	0.11	0.7458	0.17	0.6884	0.02	0.8939
CONTOUR	HEADING ERR	9	3.18	3.18	3.04	5.22	4.08	0.0781	4.05	0.0790	3.72	0.0898
	RADAR ALT	9	49.15	50.11	46.07	49.90	0.34	0.5744	0.85	0.3839	0.16	0.6991
	ROLL	9	3.31	2.76	2.93	3.65	0.63	0.4502	0.33	0.5796	3.86	0.0850
	SLIP	9	0.63	0.57	0.58	0.56	0.20	0.6641	0.46	0.5154	0.03	0.8672

Table 9b.

Repeated measures ANOVA results for flight performance RMSE.

REPEATED MEASURES ANOVA RESULTS FOR FLIGHT PERFORMANCE RMSE - TRIM OFF

RMSE FOR FLIGHT PARAMETERS BY MANEUVER							MAIN EFFECTS				INTERACTION	
							TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE(1,7)	P VALUE	F VALUE(1,7)	P VALUE	F VALUE(1,7)	P VALUE
RSRT	INDICATED ALT	9	38.66	43.38	43.13	83.31	2.87	0.1339	2.03	0.1970	1.19	0.3114
	AIR SPEED	9	2.72	2.88	2.52	3.88	3.24	0.1149	12.90	0.0091	5.54	0.0501
	ROLL ANGLE	9	3.81	3.63	4.62	5.06	3.76	0.0938	0.05	0.8252	0.26	0.6242
	TURN RATE	9	0.69	0.59	0.76	0.81	1.52	0.2578	0.05	0.8300	0.42	0.5377
LCT	AIR SPEED	9	3.91	4.09	3.88	5.94	2.10	0.1905	1.69	0.2343	2.84	0.1358
	SLIP	9	1.16	1.41	1.09	1.38	0.14	0.7231	6.50	0.0377	0.01	0.9361
	CLIMB RATE	9	294.97	306.34	290.69	374.06	2.28	0.1747	8.94	0.0202	2.19	0.1825
	TURN RATE	9	1.00	1.03	1.03	1.13	0.88	0.3807	0.88	0.3807	0.20	0.6682
SL	HEADING ERR	9	1.75	2.06	1.66	2.56	4.64	0.0682	9.31	0.0188	1.11	0.3265
	INDICATED ALT	9	53.53	59.31	43.34	60.25	1.50	0.2597	1.54	0.2540	0.22	0.6506
	AIR SPEED	9	2.91	3.16	2.94	4.06	4.94	0.0617	4.90	0.0625	0.52	0.4940
	ROLL	9	2.56	2.66	2.69	3.69	5.55	0.0507	2.45	0.1617	1.29	0.2932
	SLIP	9	0.53	0.94	0.47	1.13	0.17	0.6918	23.25	0.0019	0.74	0.4191
LDT	AIR SPEED	9	3.34	4.47	3.44	6.25	2.63	0.1492	8.40	0.0230	1.18	0.3137
	SLIP	9	1.34	1.34	1.41	1.75	1.78	0.2244	0.70	0.4313	1.26	0.2983
	CLIMB RATE	9	281.06	332.22	293.38	420.19	2.27	0.1759	15.69	0.0056	1.03	0.3447
	TURN RATE	9	1.22	1.19	1.09	1.25	0.16	0.6988	0.58	0.4700	0.76	0.4125

REPEATED MEASURES ANOVA RESULTS FOR FLIGHT PERFORMANCE RMSE - TRIM ON

RMSE FOR FLIGHT PARAMETERS BY MANEUVER							MAIN EFFECTS				INTERACTION	
							TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE(1,7)	P VALUE	F VALUE(1,7)	P VALUE	F VALUE(1,7)	P VALUE
HOV	HEADING ERR	9	1.58	1.69	1.50	1.67	0.20	0.6690	0.83	0.3885	0.02	0.9005
	RADAR ALT	9	1.33	2.22	1.39	2.89	1.88	0.2071	35.69	0.0005	0.93	0.3619
HOVT	RADAR ALT	9	1.50	2.00	1.33	2.28	0.13	0.7310	13.24	0.0066	1.94	0.2016
	TURN RATE	9	9.33	9.39	9.36	10.22	5.84	0.0429	5.50	0.0478	6.70	0.0322
RSRT	INDICATED ALT	9	25.69	26.03	27.00	38.13	1.64	0.2415	2.13	0.1882	1.53	0.2563
	AIR SPEED	9	1.91	1.75	1.53	1.88	0.34	0.5773	0.21	0.6822	1.51	0.2583
	ROLL ANGLE	9	3.09	3.19	3.53	4.13	4.21	0.0792	0.79	0.4034	0.56	0.4766
	TURN RATE	9	0.34	0.47	0.56	0.75	5.89	0.0456	1.26	0.2989	0.16	0.6986
LCT	AIR SPEED	9	2.91	2.78	2.53	2.75	0.90	0.3738	0.03	0.8724	0.37	0.5647
	SLIP	9	0.84	0.88	0.88	0.88	0.02	0.8878	0.07	0.8016	0.03	0.8687
	CLIMB RATE	9	208.19	187.63	177.53	214.44	0.01	0.9126	0.37	0.5607	2.95	0.1294
	TURN RATE	9	1.00	0.97	1.03	1.06	0.32	0.5903	0.00	1.0000	0.10	0.7560
SL	HEADING ERR	9	1.59	1.59	1.59	2.06	0.49	0.5050	0.48	0.5091	0.68	0.4378
	INDICATED ALT	9	27.75	29.44	26.28	48.13	2.06	0.1939	3.08	0.1225	2.33	0.1711
	AIR SPEED	9	1.88	2.31	1.91	2.81	0.83	0.3927	5.09	0.0294	0.39	0.5521
	ROLL	9	1.47	1.44	1.44	1.69	0.42	0.5391	0.28	0.6150	0.62	0.4579
	SLIP	9	0.16	0.09	0.13	0.19	0.18	0.6845	0.00	1.0000	1.00	0.3506
LDT	AIR SPEED	9	2.25	2.22	2.28	2.25	0.01	0.9172	0.02	0.8811	0.00	1.0000
	SLIP	9	0.16	0.09	0.09	0.25	1.00	0.3506	0.33	0.5837	1.10	0.3285
	CLIMB RATE	9	185.50	179.76	172.34	212.06	0.32	0.5916	1.57	0.2506	1.70	0.2341
	TURN RATE	9	1.19	1.00	0.94	0.88	1.80	0.2216	0.74	0.4191	0.19	0.6787
NOE	HEADING ERR	9	5.33	5.60	4.15	5.29	1.22	0.3010	1.38	0.2735	0.31	0.5921
	RADAR ALT	9	38.78	41.08	39.42	53.29	2.05	0.1897	1.46	0.2607	2.24	0.1732
	ROLL	9	4.88	4.61	4.81	5.01	0.16	0.6984	0.00	0.9487	0.14	0.7174
	SLIP	9	0.72	0.71	0.71	0.67	0.11	0.7458	0.17	0.6884	0.02	0.8939
CONTOUR	HEADING ERR	9	3.18	3.18	3.04	5.22	4.08	0.0781	4.05	0.0790	3.72	0.0898
	RADAR ALT	9	49.15	50.11	46.07	49.90	0.34	0.5744	0.85	0.3839	0.16	0.6991
	ROLL	9	3.31	2.76	2.93	3.65	0.63	0.4502	0.33	0.5796	3.86	0.0850
	SLIP	9	0.63	0.57	0.58	0.58	0.20	0.6841	0.46	0.5154	0.03	0.8672

There was not a composite RMSE equivalent to the ACS; therefore, it was not possible to perform a MANOVA on the RMSEs for all the flight variables simultaneously because of an excessive number of RMSEs compared to the relatively small sample size (nine cases). Repeated measures two-way ANOVAs (table 9a,b) were applied to determine which of the maneuver flight variable RMSEs exhibited statistically significant differences across the factor levels. Analysis was performed separately for maneuvers flown with AFCS on, off, and both on and off.

ANOVA results for flight performance RMSEs averaged across AFCS on and off for all iterations of each maneuver revealed larger RMSEs associated with the 100°F temperature on at least one variable in three (HOVT, RSRT, SL) of the eight (37.5 percent) maneuvers and with the encumbered MOPP4 ensemble for at least one variable in five (HOV, HOVT, SL, LCT, LDT) of the eight (62.5 percent) variables (table 9a,b). Larger RMSEs were associated with the 100°F temperature on 3 of 29 (10.3 percent) variables and with the encumbered MOPP4 ensemble on 8 of 29 (27.6 percent) variables. Only 1 of 29 (3.4 percent) variables exhibited a temperature by uniform interaction.

ANOVA results for flight performance RMSEs averaged only across iterations of each maneuver flown with AFCS on revealed larger RMSEs associated with the 100°F temperature on at least one variable in two (HOVT, RSRT) of the eight (25 percent) maneuvers and with the encumbered MOPP4 ensemble on at least one variable in 2 (HOV, HOVT) of the eight (25 percent) maneuvers (table 10). Larger RMSEs were associated with the 100°F temperature on 2 of 29 (6.9 percent) variables and with the encumbered MOPP4 ensemble on 3 of 29 (10.3 percent) variables. Only 1 of 29 (6.9 percent) variables exhibited a temperature by uniform interaction.

ANOVA results for flight performance RMSEs averaged only across iterations of each maneuver flown with AFCS off revealed larger RMSEs associated with the 100°F temperature on at least one variable in one (SL) of the four (25 percent) maneuvers and with the encumbered MOPP4 ensemble on at least one variable in all (SL, RSRT, LCT, LDT) of the maneuvers (table 10). Larger RMSEs were associated with the 100°F temperature on 1 of 17 (5.9 percent) variables and with the encumbered MOPP4 ensemble on 7 of 17 (41.2 percent) variables. Only 1 of 17 (5.9 percent) variables exhibited a temperature by uniform interaction.

Table 10.
Effects of encumbered MOPP4 ensemble in hot conditions on RMSE for maneuvers.

Maneuver	AFCS (trim) on & off	AFCS on	AFCS off
HOV	↑	↑	n/a
HOVT	↑	↔	n/a
RSRT	↔	↑	↑
LDT	↑	↔	↑
SL	↑	↔	↑
LCT	↑	↔	↑
Contour	↔	↔	n/a
NOE	↔	↔	n/a

* ↑ - indicates a significant increase in RMSEs.

↔ - indicates no significant increase or decrease.

Maximum and minimum values

Maximum and minimum values were obtained for each flight performance variable during each iteration of all the maneuvers. Maximum and minimum values were then averaged across iterations for each type of maneuver and test condition.

ANOVA results for maximum flight data values averaged across iterations of each maneuver flown with both AFCS on and off revealed that larger magnitudes of the maximum values were associated with the 100°F temperature for at least one variable in one of eight (12.5 percent) maneuvers and the encumbered MOPP4 for at least one variable in three of the eight (37.5 percent) maneuvers. Larger magnitude maximums were associated with the 100°F temperature in 1 of 23 (4.3 percent) variables and the encumbered MOPP4 in 3 of 23 (13 percent) variables. Only 1 of 23 (4.3 percent) variables exhibited a temperature by uniform interaction on maximums.

ANOVA results for minimum flight performance parameter values averaged across both AFCS on and off for all iterations of each maneuver revealed that adverse effects on performance were associated with the 100°F temperature for at least one variable in one of eight (12.5 percent) maneuvers and the encumbered MOPP4 for at least one

Table 11.

Fraction of maneuver types having statistically worse flight performance.

(Measured by ACS, RMSE, MAX, and MIN by data channel and AFCS status)

Trim On and Off	100°F	MOPP4	BOTH	INTERACTION
Altitude				
Score	2/6	4/6	2/6	1/6
RMSE	1/6	2/6	0/6	0/6
Max	1/6	2/6	1/6	0/6
Min	0/6	0/6	0/6	0/6
Airspeed				
Score	0/4	2/4	0/4	2/4
RMSE	1/4	2/4	1/4	0/4
Max	0/4	0/4	0/4	0/4
Min	0/4	4/4	0/4	1/4
Climb				
Score	0/2	0/2	0/2	0/2
RMSE	0/2	1/2	0/2	0/2
Max	0/2	1/2	0/2	1/2
Min	0/2	1/2	0/2	0/2
Heading				
Score	0/4	2/4	0/4	0/4
RMSE	0/4	0/4	0/4	0/4
Max	-	-	-	-
Min	-	-	-	-
Roll				
Score	1/4	2/4	0/4	1/4
RMSE	1/4	0/4	0/4	0/4
Max	0/3	0/3	0/3	0/3
Min	0/3	1/3	0/3	0/3
Slip				
Score	0/4	0/4	0/4	0/4
RMSE	0/4	2/4	0/4	0/4
Max	0/5	0/5	0/5	0/5
Min	0/4	3/4	0/4	0/4
Turn Rate				
Score	0/3	1/3	0/3	0/3
RMSE	0/3	0/3	0/3	1/3
Max	0/3	0/3	0/3	0/3
Min	1/3	2/3	1/3	0/3
TOTALS				
Score	3/27 (11.1%)	11/27 (40.1%)	2/27 (7.4%)	4/27 (14.8%)
RMSE	3/27 (11.1%)	7/27 (25.9%)	1/27 (3.7%)	1/27 (3.7%)
Max	1/23 (4.3%)	3/23 (13.0%)	1/23 (4.3%)	1/23 (4.3%)
Min	1/22 (4.5%)	11/22 (50.0%)	1/22 (4.5%)	1/22 (4.5%)
Average	6.80%	32.25%	4.98%	6.85%

Trim On	100°F	MOPP4	BOTH	INTERACTION
Altitude				
Score	1/6	3/6	1/6	1/6
RMSE	0/6	2/6	0/6	0/6
Max	0/6	1/6	0/6	0/6
Min	0/6	0/6	0/6	0/6
Airspeed				
Score	0/4	0/4	0/4	0/4
RMSE	0/4	0/4	0/4	0/4
Max	0/4	1/4	0/4	0/4
Min	0/4	1/4	0/4	0/4
Climb				
Score	0/2	0/2	0/2	0/2
RMSE	0/2	0/2	0/2	0/2
Max	0/2	0/2	0/2	0/2
Min	0/2	1/2	0/2	0/2
Heading				
Score	0/4	1/4	0/4	0/4
RMSE	0/4	0/4	0/4	0/4
Max	0/1	0/1	0/1	0/1
Min	-	-	-	-
Roll				
Score	0/4	1/4	0/4	0/4
RMSE	0/4	0/4	0/4	0/4
Max	0/3	1/3	0/3	0/3
Min	0/3	0/3	0/3	0/3
Slip				
Score	0/4	0/4	0/4	1/4
RMSE	0/4	0/4	0/4	0/4
Max	0/5	0/5	0/5	0/5
Min	0/5	4/5	0/5	0/5
Turn Rate				
Score	0/3	0/3	0/3	0/3
RMSE	1/3	0/3	0/3	0/3
Max	0/3	0/3	0/3	0/3
Min	1/3	1/3	1/3	0/3
TOTALS				
Score	1/27(3.7%)	5/27(18.5%)	1/27(3.7%)	2/27(7.4%)
RMSE	1/27(3.7%)	2/27(7.4%)	0/27(0%)	0/27(0%)
Max	0/24(0%)	3/24(12.5%)	0/24(0%)	0/24(0%)
Min	1/23(4.3%)	7/23(30.4%)	1/23(4.3%)	0/23(0%)
Average	3.00%	17.20%	11.68%	1.85%

Trim Off	100°F	MOPP4	BOTH	INTERACTION
Altitude				
Score	0/2	1/2	0/2	0/2
RMSE	0/2	0/2	0/2	0/2
Max	0/2	0/2	0/2	0/2
Min	0/2	0/2	0/2	0/2
Airspeed				
Score	0/3	2/3	0/3	0/3
RMSE	0/3	2/3	0/3	1/3
Max	0/3	1/3	0/3	1/3
Min	0/3	0/3	0/3	0/3
Climb				
Score	2/2	0/2	2/2	0/2
RMSE	0/2	2/2	0/2	0/2
Max	1/2	2/2	1/2	0/2
Min	0/2	1/2	0/2	0/2
Heading				
Score	0/1	1/1	0/1	0/1
RMSE	0/1	1/1	0/1	0/1
Max	-	-	-	-
Min	-	-	-	-
Roll				
Score	0/2	0/2	0/2	0/2
RMSE	1/2	0/2	0/2	0/2
Max	0/1	0/1	0/1	0/1
Min	0/1	0/1	0/1	0/1
Slip				
Score	0/3	0/3	0/3	0/3
RMSE	0/3	2/3	0/3	0/3
Max	0/3	0/3	0/3	0/3
Min	0/3	3/3	0/3	0/3
Turn Rate				
Score	0/3	0/3	0/3	0/3
RMSE	0/3	0/3	0/3	0/3
Max	0/3	1/3	0/3	0/3
Min	1/3	1/3	1/3	0/3
TOTALS				
Score	2/17(11.8%)	6/17(35.3%)	2/17(11.8%)	0/17(0%)
RMSE	1/17(5.9%)	7/17(41.2%)	0/17(0%)	1/17(5.9%)
Max	1/14(7.1%)	4/14(28.6%)	1/14(7.1%)	1/14(7.1%)
Min	1/14(7.1%)	5/14(35.7%)	1/14(7.1%)	0/14(0%)
Average	8.00%	35.40%	6.50%	3.25%

variable in five of the eight (37.5 percent) maneuvers. Minimums associated with worse performance were associated with the 100°F temperature in 1 of 23 (4.3 percent) variables and the encumbered MOPP4 in 10 of 23 (43.5 percent) variables. Only 1 of 23 (4.3 percent) variables exhibited a temperature by uniform interaction on minimums.

ANOVA results for maximum flight performance parameter values averaged across only those iterations of each maneuver flown with AFCS on revealed that larger maximum value magnitudes were associated with the 100°F temperature for zero of eight (0 percent) maneuvers and the encumbered MOPP4 for at least one variable in two of the eight (25 percent) maneuvers. Larger magnitude maximums were associated with the 100°F temperature in none of the variables and the encumbered MOPP4 in 2 of 25 (8 percent) variables. Only 1 of 25 (4 percent) variables exhibited a temperature by uniform interaction on maximums.

ANOVA results for minimum flight performance parameter values averaged across only those iterations of each maneuver flown with AFCS on revealed that adverse effects on performance were associated with the 100°F temperature for at least one variable in one of eight (12.5 percent) maneuvers and the encumbered MOPP4 for at least one variable in four of the eight (50 percent) maneuvers. Minimums associated with worse performance were associated with the 100°F temperature in 1 of 25 (4 percent) variables and the encumbered MOPP4 in 6 of 25 (24 percent) variables. None of the variables exhibited a temperature by uniform interaction on minimums.

ANOVA results for maximum flight performance parameter values averaged across only those iterations of each maneuver flown with AFCS off revealed that larger maximum value magnitudes were associated with the 100°F temperature for one of four (25 percent) maneuvers and the encumbered MOPP4 for at least one variable in three of the four (75 percent) maneuvers. Larger magnitude maximums were associated with the 100°F temperature in 1 of 15 (6.7 percent) variables and the encumbered MOPP4 in 4 of 15 (26.7 percent) variables. Only 1 of 15 (6.7 percent) variables exhibited a temperature by uniform interaction on maximums.

ANOVA results for minimum flight performance parameter values averaged across only those iterations of each maneuver flown with AFCS off revealed that adverse effects on performance were associated with the 100°F temperature for at least one variable in one of four (25 percent) maneuvers and the encumbered MOPP4 for at least one variable in four of the four (100 percent) maneuvers. Minimums associated with worse performance were associated with the 100°F temperature in 1 of 15 (6.7 percent) variables and the encumbered MOPP4 in 6 of 15 (40 percent) variables. None of the variables exhibited a temperature by uniform interaction on minimums.

Correlations between flight performance scores and aviator characteristics

There were no statistically significant correlations having magnitudes greater than 0.64 between average composite flight scores for the eight types of flight maneuvers (HOV, HOVT, SL, LCT, LDT, RSRT, NOE, and Contour) and personal characteristics of the volunteer aviators (age, height, weight), physical or heat stress training (PFT scores, heat illness prevention training), or flight hours (total, UH-60, and simulator). Sixteen percent of the correlations reached statistical significance. However, these had relatively small magnitudes (between 0.35 and 0.64) and therefore were not particularly useful. Eighty-four percent of the correlations between the variables were less than 0.35 in magnitude (appendix H) and not statistically significant.

Spectral analysis of cyclic and collective inputs

Two channels of data for cyclic inputs (longitudinal, i.e., fore-aft and lateral, i.e., left-right pitch deviation in degrees from a reference center-position) and one channel for collective position were obtained from the controls of right seat pilots during hover and hover turn maneuvers. The sampling rate for each channel was 10 per second (10 Hz), which allowed for a maximum input component of 5 Hz before causing aliasing effects. Control components of significant magnitude at frequencies greater than 5 Hz seemed unlikely, although no references regarding this issue were available for corroboration. Vibrations transmitted to the controls from various mechanical systems in the simulator, particularly the seat shaker that emulates engine and rotor vibration, were potential sources of higher frequency inputs into the controls. However, the power spectra visually had a smooth exponential-like decay with respect to increasing frequency that was not consistent with significant aliasing effects.

Fast Fourier Transform (FFT) analysis was performed on the cyclic and collective input data to obtain their power spectra. Power sum, peak power frequency, skewness of the power-frequency distribution, and frequencies for 10 percent, 50 percent and 90 percent cumulative power were then obtained from the FFT results for each of the four test conditions (appendix E). The zero frequency (DC) components, which represented control channel offsets, was excluded in calculating spectral results. Flight control input data for the first three right seat pilots were missing due to an inadvertent delay at the beginning of the study in initiating the software for these data acquisition channels. Therefore, six right seat pilots represented the effective sample size for the spectral analysis. Spectral results for the hover and hover turns were averaged across iterations prior to hypothesis testing.

Tabular results for cyclic and collective inputs during the hover maneuver (appendix H) revealed that total power sums were much greater for the collective input channel, while the frequency for 90 percent cumulative power was smaller for the collective than for the cyclic channels. This corresponds to larger but slower collective inputs

compared to those for the cyclic or, conversely, smaller but more rapid cyclic inputs compared to the collective. This is consistent with subjective assessments of how these controls are manipulated during routine flight.

Four- and two-way ANOVAs (appendix E) were performed on the power spectra from the collective and two cyclic channels for the hover and hover turn maneuvers. The repeated measures factors were temperature, uniform, and cumulative power levels (10, 50, and 90 percent). The independent multiple variates were the frequencies at which the specified cumulative power levels were attained for each of the three different control channels. For the hover maneuver, there were statistically significant effects with respect to temperature ($p=0.0226$), uniform ($p=0.048$), and their interaction ($p=0.0256$). However, two-way (temperature and uniform) ANOVAs per data channel and power band revealed a significant uniform effect ($p=0.0277$) only for the fore-aft cyclic control channel for the 90 percent cumulative power frequency and a temperature by uniform interaction ($p=0.0428$) for the 10 percent cumulative power frequency for the same channel. The MANOVA for the hover turn maneuver indicated marginal temperature ($p=0.0820$) and uniform ($p=0.0688$) effects, but a statistically significant temperature by uniform interaction ($p=0.0439$). However, two-way ANOVAs on the frequencies for the percent cumulative power for each data channel revealed no significant temperature, uniform, or interaction effects.

Statistical analysis of the power spectrum of cyclic and collective inputs during hover and hover turns indicated statistically significant, but poorly localized, effects of heat stress and MOPP4. The sample size (for technical reasons explained above) for this analysis, however, was too small to have much statistical power for reliably detecting small differences in power spectra between conditions.

Simulator incidents

During test sessions, pilot induced significant simulator incidents were recorded on a flight incident form (appendix I). Incidents that were tracked included main-rotor and stabilator strikes, loss of control at altitude, controlled flight into terrain, and crashes during hover or while attempting to land. The enumeration of the quantity and rates of the simulator flight incidents is delineated in appendix D. The average number of flight incidents per test session was: 2.9 for ABDU-cool, 3.1 for MOPP4-cool, 2.4 for ABDU-hot, and 0.89 for MOPP4-hot. Incident rates (number per hour) were calculated to normalize the results for differences in simulator endurance times across the four different test conditions. Total incidents per hour were: 0.69 for ABDU-cool, 0.75 for MOPP4-cool, 0.61 for ABDU-hot, and 1.08 for MOPP4-hot.

However, since there were relatively few adverse incidents, this resulted in low statistical power to detect significant differences across the test conditions. Standard deviations for the flight incidents data were also approximately of the same magnitude

as the mean number of incidents and incident rates. Consistent with this observation, two-way repeated measures ANOVA revealed no statistically significant differences across the test conditions for either cumulative number, or rates, of flight incidences.

MATB

Results for performance on the computer-based MATB were somewhat mixed (appendix F). For some variables, such as various response times and errors for the communications task, there was a significant interaction effect frequently indicating paradoxically better performance in the encumbered MOPP4-hot condition. On the other hand, keyboard entry times for responding to perceived changes in lights and dials showed a significant uniform effect with worse performance in the MOPP4 condition (appendix F). RMS tracking error also showed a statistically significant uniform effect ($p=0.0197$). RMS tracking error was 60 percent greater while wearing the encumbered MOPP4 ensemble. Temperature was a solitary factor for time out and false alarm errors for lights and dials, with more errors in the hot condition ($p=0.342$).

First order correlations between mean MATB performance variables (averaged across iterations for each test session) and average composite flight scores for each flight maneuver or flight mode (also averaged across iterations per test session) are presented in appendix H. The definitions for the MATB variables are provided in appendix H.

Correlations between MATB results and ACSs for the different maneuvers revealed no consistent pattern of correlations across test conditions. The scattered nature of the correlations that reached statistical significance was more indicative of the effects of chance or random fluctuations in unmeasured parameters rather than true associations. For this study, none of the MATB performance variables, taken individually within test conditions, were good predictors of flight performance as measured by composite scores.

Task load index questionnaire

To evaluate for possible differences in responses to the six TLX questions across the different test conditions, two-way (temperature and uniform as within test subject factors) ANOVAs were performed with task (flying the set of standard maneuvers versus performing the MATB) as a between subjects factor. The results are depicted in appendix G. There was a significant ($p=0.044$) interaction between task, temperature, and uniform for physical demand. Consistent with significant main effects for temperature ($p=0.0001$) and uniform ($p=0.005$), the mean responses showed that physical demand ratings were higher for both tasks in the hot condition and while wearing the encumbered MOPP4 ensemble. The perception of greater physical workload in the encumbered MOPP4 ensemble was exacerbated by heat stress.

Mental demand ratings exhibited only temperature ($p=0.04$) and uniform ($p=0.16$) effects. Significantly higher mental demand ratings occurred for the hot and MOPP4 conditions. Temporal demand ratings differed only with respect to uniform ($p=0.008$), with the higher ratings for the MOPP4 uniform. Performance ratings did not differ statistically across the levels of temperature, uniform, or task. Effort ratings also showed only temperature ($p=0.033$) and uniform ($p=0.002$) effects with greater subjective effort required in the hot and MOPP4 conditions. Frustration ratings were significantly ($p=0.028$) greater while wearing the encumbered MOPP4 ensemble. There was also a task-temperature interaction due to greater frustration ratings, averaged across uniforms, for flying the set of standard maneuvers compared to the MATB in the hot condition, whereas flying was less frustrating than the MATB in the cool condition.

Multiple correlations between the responses for the six TLX questions and the ACSs were performed for each of the four test conditions and the eight types of flight maneuvers (appendix H). For each condition, only 1 or 2 of the 48 cross correlations (TLX by ACS) were both statistically significant and greater in magnitude than 0.6. The location of those significant cross-correlations in the correlation matrix differed between test conditions.

Discussion

Aircrews wearing the encumbered MOPP4 BDO over ABDU aviator uniform in the hot condition incurred significantly more physiological and psychological strain as reflected in the dramatically elevated core temperature and heart rate profiles described in detail in a previous technical report (Reardon, et al., 1996). The responses to the mood and symptoms and profile of mood states questionnaires indicated significantly increased discomfort and stress for that condition. The TLX responses revealed increased perceived workload.

The existence of a statistically significant overall effect of temperature and uniform type on flight performance was confirmed by an ANOVA on the average composite flight performance scores. Subsequent ANOVA analysis on individual flight performance parameters reaffirmed the adverse effects of hot (100°F) cockpit conditions and the encumbered MOPP4 aviator uniform on flight performance. With few exceptions, the direction of flight performance parameter changes for the MOPP4-hot condition was consistently in the direction of worse performance.

UH-60 simulator flight performance

The encumbered MOPP4 ensemble adversely affected the greatest number of flight performance parameters. The hot temperature condition was second in the number of flight performance parameters adversely affected. Less frequent was adverse performance due to the simultaneous effects of MOPP4 and hot conditions, as well as temperature by uniform interactions. The pattern of factor effects was consistently maintained regardless of whether differences in flight performance, across the two temperature and uniform conditions, were analyzed as scores, RMSEs, maximums, or minimums. Flight parameter performance scores seemed to be slightly more sensitive indicators of differences in pilot performance across conditions than RMSE, maximum, or minimum values.

Composite flight performance scores were significantly decremented during UH-60 simulator flights in the MOPP4-hot condition. When averaged across flight segments flown with AFCS on and off, composite flight performance scores were adversely affected in 62.6 percent of the eight types of maneuvers. For only the segments where the AFCS was on, the average composite flight performance score was decreased in 37.5 percent of the eight maneuver types.

Evaluation of the various measures of flight performance clearly indicated significant adverse effects on pilot performance in the UH-60 simulator in the hot condition and while wearing the encumbered MOPP4 flight uniform. However, the average number and rates of simulator incidents (crashes, rotor and tail strikes, and loss of control) were not statistically worse for the hot or MOPP4 conditions.

The significant number of flight variables adversely affected by wearing the MOPP4 ensemble and heat stress were in marked contrast to the negative results reported by Hamilton et al. (1982) for a UH-1 in-flight evaluation of the effects of heat stress and standard versus several MOPP4 aviator uniforms. However, that in-flight study had greater data variance due to inability to fully control in-flight environmental conditions such as day to day variations in turbulence and other meteorological effects on aircraft controllability and performance. Our laboratory-based evaluation and use of an environmentally controlled UH-60 aircraft gave us greater statistical power to detect differences across conditions.

This study was similar to that reported by Thornton et al. in 1992. Thornton used the environmentally controlled UH-60 simulator to evaluate the standard one-piece Nomex aviator uniform and the MOPP4 AUIB ensemble in hot (WBGT = 29.4°C or 85°F) and cool (WBGT = 16.8°C or 62.24°F) conditions with and without microclimate cooling (in the hot condition). Numerous flight performance parameters were adversely affected in the hot condition and while wearing MOPP4. The parameters most frequently affected were (from most to least frequent) heading, airspeed, roll, altitude, rate of turn, vertical

speed, and slip. For this study, the most frequently affected flight performance parameters for flight segments with AFCS on were altitude, heading, and roll. With AFCS off, the most frequently affected parameters by heat stress and MOPP4 were climb/descent rates, airspeed, and altitude. However, results from this study are not exactly comparable with Thornton's results because of the considerable differences in uniforms, cockpit temperatures, and flight profiles across the two studies.

Spectral analysis of cyclic and collective input data for the hovers and hover turns was performed and revealed significant differences in control input power spectra with respect to iteration, uniform, temperature and uniform, as well as their interaction. The power spectra for cyclic and collective inputs for the hover turn only showed a temperature-uniform interaction. Further analysis of the spectral results, however, will need to be performed to determine the practical significance of the spectral differences across conditions.

TLX questionnaire

Composite TLX questionnaire results indicated that flying the simulator and performing the MATB tests were both perceived as more physically and mentally demanding, required more effort, and caused greater frustration in the MOPP4-hot condition than during the other three less stressful conditions. For the responses taken collectively, the effects of uniform (encumbered MOPP4 associated with higher ratings) had significant and adverse effects on five of the six TLX work load ratings. Temperature alone had a significant and adverse effect on three of the six ratings. Type of task as an interaction factor influenced only two of six ratings. Correlations between composite flight performance scores and TLX questionnaire responses indicated no significant linear relationship between subjective work load ratings and flight performance scores for any of the maneuvers or modes of flight.

MATB

Although the MOPP4 ensemble was associated with reduced performance on the MATB visual monitoring and tracking tasks, MATB performance did not correlate consistently with flight performance scores. These results, therefore, do not appear to support the use of the MATB as a predictor of flight performance or its use as a surrogate for simulator-based evaluation of the effects of heat stress and different types of aviator uniforms on flight performance. On the other hand, this study was not designed specifically to define or validate predictive relationships between the MATB and UH-60 simulator flight performance. For example, although the MATB tracks reaction times as well as detection failures and false alarms for the simulated warning lights and dials subtask, a corresponding method for capturing similar stimuli and responses for the pilots flying the simulator was not incorporated. That is, data were not collected on the effects of heat stress and MOPP4 on responsivity to visual

detection of changes in actual cockpit instruments nor for simulated radio transmissions and radio frequency changes for the actual radios in the simulator. That would have entailed an additional experiment. Therefore, the extent to which the MATB can predict performance in the UH-60 simulator for a similar range of tasks was not really resolved in this study.

Conclusions

The preponderance and consistency of the statistically significant flight performance results indicated that heat stress and the encumbered MOPP4 ensemble adversely affected pilot endurance and performance in the UH-60 simulator. The encumbered MOPP4 ensemble was the most frequent cause of decrements in flight performance. Next in frequency of adverse effects was heat stress, followed by the interaction effects of both heat stress and the encumbered MOPP4 uniform. The operational significance of the flight performance decrements alone, however, is uncertain since neither heat stress nor the encumbered MOPP4 ensemble were associated with higher rates of simulator crashes or other potentially catastrophic in-flight incidents. Nevertheless, as detailed in a preceding technical report (Reardon et al. 1996) on the physiological and psychological results, the effects of wearing the encumbered MOPP4 flight uniform in the hot condition caused large increases in core and skin temperatures, heart rates, sweat rates, and increases in perceived workload and symptoms of discomfort and stress.

Mission completion rates were zero in the MOPP4-hot condition because of the severe physiological and psychological strain that occurred within 2 hours of exposure. Endurance times in that condition were most frequently limited by having reached safety restrictions for core temperature and heart rate. Some crews could probably have continued for a limited time longer after reaching the safety limits. However, it is likely that without the safety limits, they eventually would have succumbed to severe heat exhaustion or heat stroke. On the other hand, it is also plausible that in an operational setting, the pilots would have actually had lower endurance times in MOPP4-hot conditions if the study conditions inadvertently provided artificially elevated levels of motivation. Likewise, in actual aircraft, the crews might have discontinued the missions sooner because of concerns about the effects of heat stress on the risk of crashing and the possibility of severe consequences to themselves and their passengers.

Performance on the MATB computer test also revealed performance decrements associated with cockpit heat stress and wearing the encumbered MOPP4 ensemble. Reaction times and errors for detecting and responding to changes in simulated warning lights and strip gauges and RMSE for target tracking were significantly worse in the hot and MOPP4 conditions. However, it was not possible to fully and fairly compare MATB and simulator performance results because this study was not designed or able

to capture similar data for responses to changes in lights and dials for the actual cockpit instrument panel. It will require a separate study to validate all the MATB components with respect to similar tasks in the UH-60 simulator.

There were no consistent, statistically significant, correlations between flight performance scores or MATB performance measures and test subject characteristics such as age, morphology, flight history, physical training test performance, and amount of heat stress training. Likewise, there were no consistent correlations between flight performance scores and MATB results or between flight performance scores and TLX questionnaire ratings within conditions. The average responses for most of the TLX questions, however, were significantly different with respect to the two temperature and uniform conditions with higher workload ratings for the hot and encumbered MOPP4 conditions. There were no significant differences in workload ratings between flying the set of standard maneuvers and the MATB performance test.

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Appendix A. Flight scripts.

Table A-1.
Air assault scenario.

Time	Man	WP	Action	Maneuver	Min	Km	Standards	Variables to score	Notes
1	1	1	Manual start/stop	Hover	1		hdg 360° ,10 ft	Alt, drift, hdg	
2	2	1	Manual start/stop	Hover turn (360°)	1		10 ft	Alt, drift, turn rate	
5	3	1	Manual start	Contour to wp2	3	10.9	var AS, const alt	Alt,grnd track,roll,trim	Admin Mood/Symptom
7.5	4	2	Auto stop/start	Contour to wp3	2.5	10.5	var AS, const alt	Alt, grnd track, roll, trim	
11.5		3	Auto stop	Arrived at wp3 Ascend to 2k'	4			None	Cue Co-pilot to prepare for MATB
12.5	5	3+	Manual start/stop	S&L	1		270°,2k', 120kts	AS, alt, trim, roll, hdg	Cue Co-pilot to begin MATB
14.5	6	3+	Manual start/stop	360° RSRT	2		to hdg 270°,2k',120kts	AS, alt, trim, roll, turn rate	
15.5	7	3+	Manual start/stop	S&L	1		270°,2k',120kts	AS, alt, trim, roll, hdg	
16.5	8	3+	Manual start/stop	L, 180°, I SRT	1		to hdg 090°,2k → 2.5k',120kts	AS, trim, roll, turn rate, ascent rate	
17.5	9	3+	Manual start/stop	S&L	1		090°,2.5k',120kts	AS, alt, trim, roll, hdg	
18.5	10	3+	Manual start/stop	L, 180°, I SRT	1		to hdg 270°,2.5k → 2k',120kts	AS, trim, roll, turn rate, descent rate	
19.5	11	3+	Manual start/stop	S&L	1		270°,2.0k',120kts	AS, alt, trim, roll, hdg	
21.5	12	3+	Manual start/stop	Descend then go to wp4	2		270°,2 → 1k',120kts	AS, trim, roll, hdg, descent rate	Administer TLX to pilot
25	13	4	Auto start	Contour to wp5	3.5	13.4	var AS, const alt	Alt, grnd track, roll, trim	Admin TLX to Co-pilot at end of MATB
26	14	5	Auto stop/start	NOE to wp6	1	3.3	var AS, var alt<25	Alt, grnd track, roll, trim	

Table A-1(continued).
Air assault scenario.

Time	Man	WP	Action	Maneuver	Min	Km	Standards	Variables to score	Notes
		6	Auto stop	Arrived at wp6				None	
27	15	6	Manual start/stop	Hover	1		hdg 360°, 10 ft	Alt, drift, hdg	
28	16	6	Manual start/stop	Hover turn (360°)	1		10 ft	Alt, drift, turn rate	
29.8	17	6	Auto start	Contour to wp7	1.8	5.3	var AS, const alt	Alt,grnd track,roll,trim	Admin Mood/Symptom
33.8		7	Auto stop	Arrived at wp7 Ascend to 2k'	4			None	Cue Co-pilot to prepare for MATB
34.8	18	7+	Manual start/stop Trim off	S&L	1		270°,2k', 120kts	AS, alt, trim, roll, hdg	Cue Co-pilot to begin MATB
36.8	19	7+	Manual start/stop	360° RSRT	2		to hdg 270°,2k',120kts	AS, alt, trim, roll, turn rate	
37.8	20	7+	Manual start/stop	S&L	1		270°,2k',120kts	AS, alt, trim, roll, hdg	
38.8	21	7+	Manual start/stop	L, 180°, ISRT	1		to hdg 090°,2k → 2.5k',120kts	AS, trim, roll, turn rate, ascent rate	
39.8	22	7+	Manual start/stop	S&L	1		090°,2.5k',120kts	AS, alt, trim, roll, hdg	
40.8	23	7+	Manual start/stop	L, 180°, ISRT	1		to hdg 270°,2.5k → 2k',120kts	AS, trim, roll, turn rate, descent rate	
42.8	24	7+	Manual start/stop	S&L	1		270°,2k',120kts	AS, alt, trim, roll, hdg	
43.8	25	7+	Manual start/stop Trim on	Descend then go to wp8	2		270°,2k → 1k',120kts	AS, trim, roll, hdg, descent rate	Administer TLX to Pilot
46.8	26	8	Auto start	Contour to wp9	3	12.5	var AS, const alt	Alt, grnd track, roll, trim	Admin TLX to Co-pilot at end of MATB
49.8	27	9	Auto stop/start	Contour to wp10	3	11.6	var AS, const alt	Alt, grnd track, roll, trim	

Table A-1(continued).
Air assault scenario.

Time	Man	WP	Action	Maneuver	Min	Km	Standards	Variables to score	Notes
53.3	28	10	Auto stop/start	Contour to wp11	3.5	13	var AS, const alt	Alt, grnd track, roll, trim	Admin Mood/Symptom
57.8	29	11	Auto start	Contour to wp12	4.5	16	var AS, const alt	Alt, grnd track, roll, trim	
60.3	30	12	Auto stop/start	NOE to wp13	2.5	8.7	var AS, var alt<25	Alt, grnd track, roll, trim	
62.8	31	13	Auto stop/start	Noe to wp6	2.5	8	Vas AS Var Alt <25	Alt,grnd track,roll,trim	
		6	Auto stop	Arrive wp6			hdg 360°, 10 ft	None	
63.8	32	6	Manual start/stop	Hover	1		Hdg 360°,10 ft	Alt,drift,Hdg	
64.8	33	6	Manual start/stop	Hover turn (360°)	1		10 ft	Alt, drift, turn rate	
66.6	34	6	Manual start	Contour to wp7	1.8	5.3	var AS, const alt	Alt,grnd track,roll, trim	
70.6		7	Auto stop	Arrived at wp7 Ascend to 2k'	4			None	Cue Co-pilot to prepare for MATB
71.6	35	7+	Manual start/stop	S&L	1		270°,2k',120kts	AS, alt, trim, roll, hdg	Cue Co-pilot to begin MATB
73.6	36	7+	Manual start/stop	360° RSRT	2		270°,2k',120kts	AS, alt, trim, roll, turn rate	
74.6	37	7+	Manual start/stop	S&L	1		270°,2k',120kts	AS, alt, trim, roll, hdg	
75.6	38	7+	Manual start/stop	L, 180°, I SRT	1		to hdg 090°,2k - 2.5k',120kts	AS, trim, roll, turn rate, ascent rate	
76.6	39	7+	Manual start/stop	S&L	1		090°,2.5k',120kts	AS, alt, trim, roll, hdg	
77.6	40	7+	Manual start/stop	L, 180°, I SRT	1		to hdg 270°,2.5k - 2k',120kts	AS, trim, roll, turn rate, descent rate	
78.6	41	7+	Manual start/stop	S&L	1		270°,2.0k',120kts	AS, alt, trim, roll, hdg	

Table A-1(continued).
Air assault scenario.

Time	Man	WP	Action	Maneuver	Min	Km	Standards	Variables to score	Notes
80.6	42	7+	Manual start/stop	Descend then go to wp8	2		270°,2 → 1k',120kts	AS, trim, roll, hdg, descent rate	Administer TLX to pilot
83.6	43	8	Auto start	Contour to wp9	3	12.5	var AS, const alt	Alt, grnd track, roll, trim	Admin TLX to Co-pilot at end of MATB
86.6	44	9	Auto stop	Contour to wp10	3	11.6	var AS, const alt	Alt, grnd track, roll, trim	Admin Mood/Symptom
89.6	45	10		Contour to wp14	3	12.2	var AS, const alt	Alt, grnd track, roll, trim	
91.6	46	14	Auto start	NOE to wp15	2	10	var AS, var alt<25	Alt, grnd track, roll, trim	
95.6		15	Auto stop	Arrive at wp15 Ascend to 2K'	4			None	Cue Co-pilot to prepare for MATB
96.6	47	15+	Manual start/stop Trim off	S&L	1		090°,2k',120kts	AS, alt, trim, roll, hdg	Cue Co-pilot to begin MATB
98.6	48	15+	Manual start/stop	360° RSRT	2		090°,2k',120kts	AS, alt, trim, roll, turn rate	
99.6	49	15+	Manual start/stop	S&L	1		090°,2k',120kts	AS, alt, trim, roll, hdg	
100.6	50	15+	Manual start/stop	L, 180°, I SRT	1		to hdg 270°,2k → 2.5k',120kts	AS, trim, roll, turn rate, ascent rate	
101.6	51	15+	Manual start/stop	S&L	1		270°,2.5k',120kts	AS, alt, trim, roll, hdg	
102.6	52	15+	Manual start/stop	L, 180°, I SRT	1		to hdg 090°,2.5k → 2k',120kts	AS, trim, roll, turn rate, descent rate	
103.6	53	15+	Manual start/stop	S&L	1		090°,2.0k', 120kts	AS, alt, trim, roll, hdg	
105.6	54	15+	Manual start/stop Trim on	Descend then go to wp16	2		090°,2 → 1k', 120kts	AS, trim, roll, hdg, descent rate	Administer TLX to pilot
108.6	55	16	Auto start	Contour to wp1	3	12.4	var AS, const alt	Alt, grnd track, roll, trim	Admin TLX to Co-pilot at end of MATB

Table A-1(continued).
Air assault scenario.

Time	Man	WP	Action	Maneuver	Min	Km	Standards	Variables to score	Notes
		1	Auto stop	Arrived at wp1				None	
109.6	56	1	Manual start/stop	Hover	1		hdg 360° ,10 ft	Alt, drift, hdg	
110.6	57	1	Manual start/stop	Hover turn (360°)	1		10 ft	Alt, drift, turn rate	Admin Mood/Symptom At end of maneuver
				Total	110.6				

Table A-2.
MEDEVAC scenario.

Time	Man	WP	Action	Maneuver	Mins	Km	Standards	Variables to score	Notes
1	1	18	Manual start/stop	Hover	1		10 ft alt, 360°hdg	Alt, drift, hdg	
2	2	18	Manual start/stop	Hover turn (360°)	1			Alt, drift, turn rate	
7.3	3	19	Manual start	Contour to wp19	5.3	20	var AS, const alt	Alt, grnd track, roll, trim	Admin Mood/Symptoms
11.3		19	Auto stop	Reached wp19 Ascend to 2k'	4				Cue Co-pilot to prepare for MATB
12.3	4	19+	Manual start/stop	S&L	1		120kts,2k',180°	AS, alt, trim, roll, hdg	Cue Co-pilot to begin MATB
14.3	5	19+	Manual start/stop	RSRT	2		360°	AS, alt, trim, roll, turn rate	
15.3	6	19+	Manual start/stop	S&L	1		120kts,2k',180°	AS, alt, trim, roll, hdg	
16.3	7	19+	Manual start/stop	L, 180°,↑SRT	1		2.0k→2.5k'	AS, trim, roll, turn rate, ascent rate	
17.3	8	19+	Manual start/stop	S&L	1		120kts,2.5k',360°	AS, alt, trim, roll, hdg	
18.3	9	19+	Manual start/stop	L, 180°,↓SRT	1		2.5k →2k'	AS, trim, roll, turn rate, descent rate	
19.3	10	19+	Manual start/stop	S&L	1		120kts,2.0k',180°	AS, alt, trim, roll, hdg	
21.3	11	19+	Manual start/stop	Descend then go to wp20	2		120kts,2.0 → 1.0k',180°	AS, trim, roll, hdg, descent rate	Administer TLX to pilot
23.3	12	20	Auto start	Contour to wp21	2	8.4	var AS, const alt	Alt, grnd track, roll, trim	Admin TLX to Co-pilot at end of MATB
26.3	13	21	Auto stop/start	Contour to wp22	3	11.8	var AS, var alt<25	Alt, grnd track, roll, trim	Admin Mood/Symptoms
30.3	14	22	Auto stop/start	NOE to wp23	4	14.8	var AS, var alt<25	Alt, grnd track, roll, trim	
34.3		23	Auto stop	Arrive at wp23 Ascend to 2k'	4			None	Cue Co-pilot to prepare for MATB
35.3	15	23+	Manual start/stop Trim off	S&L	1		120kts,2k',270°	AS, alt, trim, roll, hdg	Cue Co-pilot to begin MATB

Table A-2 (continued).
MEDEVAC scenario.

Time	Man	WP	Action	Maneuver	Mins	Km	Standards	Variables to score	Notes
37.3	16	23+	Manual start/stop	RSRT	2		360°	AS, alt, trim, roll, turn rate	
38.3	17	23+	Manual start/stop	S&L	1		120kts,2k',270°	AS, alt, trim, roll, hdg	
39.3	18	23+	Manual start/stop	L, 180°, ↑SRT	1		2.0k → 2.5k'	AS, trim, roll, turn rate, ascent rate	
40.3	19	23+	Manual start/stop	S&L	1		120kts,2.5k',090°	AS, alt, trim, roll, hdg	
41.3	20	23+	Manual start/stop	L, 180°,↓SRT	1		2.5k → 2k'	AS, trim, roll, turn rate, descent rate	
42.3	21	23+	Manual start/stop	S&L	1		120kts,2.0k',270°	AS, alt, trim, roll, hdg	
44.3	22	23+	Manual start/stop Trim on	Descend then go to wp24	2		120kts,2.0k',→ 1.0k',270°	AS, trim, roll, hdg, descent rate	Administer TLX to pilot
47.3	23	24	Auto start	Contour to wp25	3	10.6	var AS, const alt	Alt, grnd track, roll, trim	Admin TLX to Co-pilot at end of MATB
49.3	24	25	Auto stop/start	NOE to wp26	2	10	var AS, var alt<25'	Alt, grnd track, roll, trim	
		26	Auto stop	Arrived at wp26				None	
50.3	25	26	Manual start/stop	Hover	1		10 ft alt, 360° hdg	Alt, drift, hdg	
51.3	26	26	Manual start/stop	Hover turn (360°)	1		10 ft alt	Alt, drift, turn rate	
53.8	27	26	Manual start	Contour to wp27	2.5	9	var AS, const alt	Alt, grnd track, roll, trim	Admin Moods/Symptoms
56.8	28	27	Auto stop/start	Contour to wp28	3	12.5	var AS, const alt	Alt, grnd track, roll, trim	
60.3	29	28		Contour to wp 29	3.5	13.5		Alt, grnd track, roll, trim	
64.3		29	Auto stop	Arrived at wp29 Ascend to 2k'	4			None	Cue Co-pilot to prepare for MATB
65.3	30	29+	Manual start/stop	S&L	1		120kts,2k',090°	AS, alt, trim, roll, hdg	Cue Co-pilot to begin MATB
67.3	31	29+	Manual start/stop	RSRT	2		360°	AS, alt, trim, roll, turn rate	

Table A-2 (continued).
MEDEVAC scenario.

Time	Man	WP	Action	Maneuver	Mins	Km	Standards	Variables to score	Notes
68.3	32	29+	Manual start/stop	S&L	1		120kts,2k',090°	AS, alt, trim, roll, hdg	
69.3	33	29+	Manual start/stop	L, 180°, ↑SRT	1		2.0k →2.5k'	AS, trim, roll, turn rate, ascent rate	
70.3	34	29+	Manual start/stop	S&L	1		120kts,2.5k',270°	AS, alt, trim, roll, hdg	
71.3	35	29+	Manual start/stop	L, 180°, ↓SRT	1		2.5k → 2k'	AS, trim, roll, turn rate, descent rate	
72.3	36	29+	Manual start/stop	S&L	1		120kts,2.0k',090°	AS, alt, trim, roll, hdg	
74.3	37	29+	Manual start/stop	Descend then go to wp 30	2		120kts,2.0→ 1.0K',090°	AS, trim, roll, hdg, descent rate	Administer TLX to pilot
75.3	38	30	Auto start	Contour to wp31	1	4	var AS, const alt	Alt, grnd track, roll, trim	Admin TLX to Co-pilot at end of MATB
79.8	39	31	Auto stop/start	NOE to wp32	4.5	16.6	var AS, var alt<25	Alt, grnd track, roll, trim	
87.3	40	32	Auto stop/start	Contour to wp33	7.5	28.2	var AS, const alt	Alt,grnd track,roll,trim	Admin Mood/Symptoms
96.3	41	33	Auto stop/start	Contour to wp34	9	33.1	var AS, const alt	Alt,grnd track,roll ,trim	
100.3		34	Auto stop	Arrive wp 34 Ascend to 2k'	4		var AS, const alt	Alt, grnd track, roll, trim	Cue Co-pilot to for MATB prepare
101.3	42	34+	Manual start/stop Trim off	S&L	1		120kts,2k',090°	AS, alt, trim, roll, hdg	Cue Co-pilot to begin MATB
103.3	43	34+	Manual start/stop	RSRT	2		360°	AS, alt, trim, roll, turn rate	
104.3	44	34+	Manual start/stop	S&L	1		120kts,2k',90°	AS, alt, trim, roll, hdg	
105.3	45	34+	Manual start/stop	L, 180°,↑SRT	1		2.0k → 2.5k'	AS, trim, roll, turn rate, ascent rate	
106.3	46	34+	Manual start/stop	S&L	1		120kts,2.5k',270°	AS, alt, trim, roll, hdg	
107.3	47	34+	Manual start/stop	L, 180°, ↓SRT	1		2.5k→ 2k'	AS, trim, roll, turn rate, descent rate	
108.3	48	34+	Manual start/stop	S&L	1		120kts,2.0k',090°	AS, alt, trim, roll, hdg	

Table A-2 (continued).
MEDEVAC scenario.

Time	Man	WP	Action	Maneuver	Mins	Km	Standards	Variables to score	Notes
109.3	49	34+	Manual start/stop Trim on	Descend then go to wp35	1		120kts,2.0→ 1.0k ,090°	AS, trim, roll, hdg, descent rate	Administer TLX to pilot
112.3	50	35	Auto start	Contour to wp36	3	12.5	var AS, const alt	Alt, grnd track, roll, trim	Admin TLX to Co-pilot at end of MATB
116.3	51	36	Auto stop/start	NOE to wp18	4	6.5	var AS, var alt<25	Alt, grnd track, roll, trim	
		18	Auto stop	Arrived at wp18				None	
117.3	52	18	Manual start/stop	Hover	1		10 ft alt, 360 hdg	Alt, drift, hdg	
118.3	53	18	Manual start/stop	Hover turn (360°)	1		10 ft alt	Alt, drift, turn rate	Admin Mood/Symptoms when maneuver complete
				Total	118.3				

Appendix B. Test subject demographics.

Table B-1.

Demographics.

Test Subjects	RANK	GENDER	HAVE YOU EVER BEEN A TEST SUBJECT IN OTHER STUDIES	WHAT AIRCRAFT ARE YOU RATED IN	ADDITIONAL AVIATOR QUALIFICATIONS	TOTAL FLIGHT HOURS AS A PILOT	UH-60 PILOT FLIGHT HOURS	UH-60 SIMULATOR PILOT HOURS	NBC OVERGARMENT AND MASK PAST YEAR (HRS)
1	MAJ	FEMALE	YES	UH-1, UH-60	FW MULTI-ENGINE	1100	500	100	0
2	CW4	MALE	NO	UH-60	UH-1, OH-58	2800	40	8	0
3	CW3	MALE	NO	UH-1, OH-58, TH-55, AH-1, UH-60	N/A	2200	300	40	1
4	1LT	MALE	NO	UH-1, OH-58	N/A	320	0	8	0
5	CW3	MALE	NO	UH-1 H & M, AH-1	N/A	1750	0	2	1
6	WO1	MALE	NO	UH-1, UH-60	N/A	200	17	9	0
7	CW2	MALE	NO	UH-60, UH-1	N/A	695	530	45	1
8	CW2	MALE	NO	UH-60, UH-1	N/A	630	540	90	2
9	CW3	MALE	NO	TH-55, UH-1, OH-58, UH-60	SEL PRIVATE PILOT	4000	120	40	3
10	MAJ	MALE	NO	AH-1, OH-58, UH-1	IP, NVG IP	1500	0	0	0
11	CW2	FEMALE	YES	153D, UH-60A	UH-1H	450	25	20	0
12	CW3	MALE	NO	UH-60, UH-1	N/A	2300	1800	160	0
13	CW3	MALE	YES	UH-60, UH-1, OH-58	MTP ALL THREE A/C	1800	1500	300	0
14	CW2	MALE	YES	UH-1, UH-60	MEDEVAC	600	500	150	1

Table B-1. (continued)

Demographics.

Test Subjects	NBC OVERGARMENT AND MASK PAST 5 YEARS (HRS)	AGE	HEIGHT (INCHES)	WEIGHT (POUNDS)	MOST RECENT PT TEST	PUSHUPS	SITUPS	RUN TIME	ESTIMATE OF PERCENTAGE OF MAXIMUM EFFORT (0-100%)	HOW MANY TIMES PER WEEK YOU DO PT	TOTAL HOURS OF PHYSICAL TRAINING PER WEEK	TOTAL HRS TRAINING IN HEAT CASUALTY OVER PAST TWO YEARS
1	0	36	67	134	6/1/95	35	65	19:00	100	3	3	0
2	0	49	70	170	10/1/95	30	30	16:30	80	1	1	0
3	5	33	69	155	11/1/95	55	55	14:30	90	4	4	3
4	1	29	71	175	12/15/95	67	92	12:10	100	6	6	1
5	7	50	68	192	4/13/96	37	31	18:35	90	3	3	0
6	0	28	71	170	3/1/96	65	88	1430	85	4	4	0
7	3	31	74	190	4/1/96	50	47	16:24	85	3	3	1
8	8	32	71	198	5/1/96	40	45	15:38	70	3	3	0
9	18	32	72	178	2/1/96	46	56	15:10	100	2	2	6
10	4	44	71	175	5/10/96	75	80	14:20	100	3	3	0
11	5	32	65	142	4/1/96	48	81	17:30	90	7	10.5	3
12	4	34	67	165	7/1/96	75	64	14:10	70	3	3	0
13	52	41	68	175	11/1/95	80	80	13:20	100	5	5	0
14	5	27	70	155	4/1/96	60	70	15:00	90	3	4.5	4

Appendix C. Flight performance tables.

Table C-1.

Three-way ANOVA for flight performance: ACS scores.

	df Effect	MS Effect	df Error	MS Error	F	p-level
Temperature	1	46.1354866	6	14.5303831	3.17510462	0.12505038
Uniform	1	336.404663	6	35.2711411	9.53767395	0.02143401
Maneuver	7	5235.67676	42	33.5712357	155.95723	5.958E-28
Temperature and Uniform	1	231.884186	6	19.8358612	11.6901493	0.01415962
Temperature and Maneuver	7	19.4433289	42	18.3728714	1.05826294	0.40672061
Uniform and Maneuver	7	18.7493668	42	21.1050053	0.88838476	0.52411926
Temperature, Uniform, and Maneuver	7	8.49224949	42	19.697401	0.43113554	0.87712443

Table C-2.

MANOVA for flight performance using average scores.

Summary of all effects for all variables taken simultaneously

Manova for Flight Performance: Scores-Contour

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.01537	51.2590	5	4	0.0010
Uniform	0.02958	26.2477	5	4	0.0037
Temperature and Uniform	0.01110	71.2675	5	4	0.0005

Manova for Flight Performance: Scores-Left Descending Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.01701	34.6761	5	3	0.0074
Uniform	0.01721	34.2610	5	3	0.0075
Temperature and Uniform	0.00773	76.9974	5	3	0.0023

Manova for Flight Performance: Scores-Hover Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00237	841.7723	3	6	0.0000
Uniform	0.00194	1026.6421	3	6	0.0000
Temperature and Uniform	0.00323	616.8964	3	6	0.0000

Manova for Flight Performance: Scores-NOE

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.01408	56.0376	5	4	0.0009
Uniform	0.01188	66.5235	5	4	0.0006
Temperature and Uniform	0.01551	50.7665	5	4	0.0010

Manova for Flight Performance: Scores-Hover

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.16455	10.1546	3	6	0.0091
Uniform	0.09645	18.7364	3	6	0.0019
Temperature and Uniform	0.23414	6.5421	3	6	0.0255

Manova for Flight Performance: Scores-RSRT

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.05033	11.3202	5	3	0.0366
Uniform	0.08553	6.4152	5	3	0.0785
Temperature and Uniform	0.00518	115.2969	5	3	0.0013

Manova for Flight Performance: Scores-Left Climbing Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00734	81.1446	5	3	0.0021
Uniform	0.01412	41.8841	5	3	0.0056
Temperature and Uniform	0.00193	310.9716	5	3	0.0003

Manova for Flight Performance: Scores-Straight & Level

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.01796	18.2218	6	2	0.0529
Uniform	0.00064	521.4200	6	2	0.0019
Temperature and Uniform	0.02820	11.4884	6	2	0.0822

Table C-3.

MANOVA for flight performance using the average maximum scores.

Summary of all effects for all variables taken simultaneously

Manova for Flight Performance: Max Scores-Contour

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00293	425.8351	4	5	0.0000
Uniform	0.07325	15.8157	4	5	0.0048
Temperature and Uniform	0.04652	25.6188	4	5	0.0016

Manova for Flight Performance: Max Scores-Left Descending Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.24794	3.0332	4	4	0.1539
Uniform	0.06555	14.2546	4	4	0.0123
Temperature and Uniform	0.24873	3.0204	4	4	0.1548

Manova for Flight Performance: Max Scores-Hover Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00848	409.3405	2	7	0.0000
Uniform	0.85662	0.5858	2	7	0.5818
Temperature and Uniform	0.72632	1.3188	2	7	0.3265

Manova for Flight Performance: Max Scores-NOE

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00099	1262.4877	4	5	0.0000
Uniform	0.02483	49.0893	4	5	0.0003
Temperature and Uniform	0.02119	57.7325	4	5	0.0002

Manova for Flight Performance: Max Scores-Hover

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.01327	260.2046	2	7	0.0000
Uniform	0.51294	3.3235	2	7	0.0967
Temperature and Uniform	0.57646	2.5715	2	7	0.1454

Manova for Flight Performance: Max Scores-RSRT

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00006	27702.6621	3	5	0.0000
Uniform	0.00007	24887.3125	3	5	0.0000
Temperature and Uniform	0.00008	21544.9570	3	5	0.0000

Manova for Flight Performance: Max Scores-Left Climbing Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00209	478.4815	4	4	0.0000
Uniform	0.00122	815.6205	4	4	0.0000
Temperature and Uniform	0.00207	481.6010	4	4	0.0000

Manova for Flight Performance: Max Scores-Straight & Level

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00001	61941.0156	5	3	0.0000
Uniform	0.00001	41145.5156	5	3	0.0000
Temperature and Uniform	0.00002	32336.3105	5	3	0.0000

Table C-4.

MANOVA for flight performance using the average minimum scores.

Summary of all effects for all variables taken simultaneously

Manova for Flight Performance: Min Scores-Contour

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00094	1332.4218	4	5	0.0000
Uniform	0.00459	271.2743	4	5	0.0000
Temperature and Uniform	0.00324	384.1965	4	5	0.0000

Manova for Flight Performance: Min Scores-Left Descending Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00867	114.3704	4	4	0.0002
Uniform	0.01675	58.7030	4	4	0.0008
Temperature and Uniform	0.00861	115.1974	4	4	0.0002

Manova for Flight Performance: Min Scores-Hover Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00130	2679.0964	2	7	0.0000
Uniform	0.78659	0.9496	2	7	0.4316
Temperature and Uniform	0.82520	0.7414	2	7	0.5105

Manova for Flight Performance: Min Scores-NOE

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00007	16766.7441	4	5	0.0000
Uniform	0.00060	2095.5991	4	5	0.0000
Temperature and Uniform	0.00040	3097.7803	4	5	0.0000

Manova for Flight Performance: Min Scores-Hover

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.58043	2.5300	2	7	0.1490
Uniform	0.78183	0.9767	2	7	0.4226
Temperature and Uniform	0.79181	0.9203	2	7	0.4417

Manova for Flight Performance: Min Scores-RSRT

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00002	93536.8672	3	5	0.0000
Uniform	0.00002	101909.7656	3	5	0.0000
Temperature and Uniform	0.00001	152210.5156	3	5	0.0000

Manova for Flight Performance: Min Scores-Left Climbing Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.08544	10.7043	4	4	0.0207
Uniform	0.52482	0.9054	4	4	0.5372
Temperature and Uniform	0.08056	11.4126	4	4	0.0184

Manova for Flight Performance: Min Scores-Straight & Level

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00000	236378.9063	4	4	0.0000
Uniform	0.00001	76238.8750	4	4	0.0000
Temperature and Uniform	0.00001	152284.5313	4	4	0.0000

Table C-5.

MANOVA for flight performance using means from the average statistics.

Summary of all effects for all variables taken simultaneously

Manova for Flight Performance: Statistics-Contour

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00075	1676.3248	4	5	0.0000
Uniform	0.24695	3.8118	4	5	0.0874
Temperature and Uniform	0.24388	3.8754	4	5	0.0849

Manova for Flight Performance: Statistics-Left Descending Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00076	1311.5732	4	4	0.0000
Uniform	0.00243	411.3374	4	4	0.0000
Temperature and Uniform	0.00076	1312.9890	4	4	0.0000

Manova for Flight Performance: Statistics-Hover Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00096	3635.7266	2	7	0.0000
Uniform	0.90445	0.3698	2	7	0.7036
Temperature and Uniform	0.11558	26.7815	2	7	0.0005

Manova for Flight Performance: Statistics-NOE

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00029	4384.5537	4	5	0.0000
Uniform	0.00181	687.8862	4	5	0.0000
Temperature and Uniform	0.00193	646.9161	4	5	0.0000

Manova for Flight Performance: Statistics-Hover

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.02883	118.7313	2	7	0.0000
Uniform	0.85193	0.6083	2	7	0.5707
Temperature and Uniform	0.86422	0.5499	2	7	0.6000

Manova for Flight Performance: Statistics-RSRT

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00002	76945.7891	3	5	0.0000
Uniform	0.00002	76244.6719	3	5	0.0000
Temperature and Uniform	0.00002	96795.2422	3	5	0.0000

Manova for Flight Performance: Statistics-Left Climbing Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00278	358.3568	4	4	0.0000
Uniform	0.00081	1241.1550	4	4	0.0000
Temperature and Uniform	0.00288	349.1764	4	4	0.0000

Manova for Flight Performance: Statistics-Straight & Level

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.00002	50546.2188	4	4	0.0000
Uniform	0.00004	22979.2070	4	4	0.0000
Temperature and Uniform	0.00003	30664.5781	4	4	0.0000

Table C-6.

MANOVA for flight performance using means from the standard deviation statistics.

Summary of all effects for all variables taken simultaneously

Manova for Flight Performance: Statistics-Contour

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.01453	84.7827	4	5	0.0001
Uniform	0.03240	37.3255	4	5	0.0006
Temperature and Uniform	0.01479	83.2661	4	5	0.0001

Manova for Flight Performance: Statistics-Left Descending Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.03751	25.6627	4	4	0.0041
Uniform	0.03714	25.9222	4	4	0.0040
Temperature and Uniform	0.03729	25.8201	4	4	0.0041

Manova for Flight Performance: Statistics-Hover Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.05015	66.2912	2	7	0.0000
Uniform	0.78071	0.9831	2	7	0.4205
Temperature and Uniform	0.81140	0.8135	2	7	0.4812

Manova for Flight Performance: Statistics-NOE

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.01312	94.0164	4	5	0.0001
Uniform	0.01874	65.4556	4	5	0.0002
Temperature and Uniform	0.01529	80.5126	4	5	0.0001

Manova for Flight Performance: Statistics-Hover

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.06476	50.5471	2	7	0.0001
Uniform	0.53795	3.0062	2	7	0.1142
Temperature and Uniform	0.54218	2.9555	2	7	0.1174

Manova for Flight Performance: Statistics-RSRT

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.02954	54.7464	3	5	0.0003
Uniform	0.03137	51.4606	3	5	0.0004
Temperature and Uniform	0.02922	55.3669	3	5	0.0003

Manova for Flight Performance: Statistics-Left Climbing Turn

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.01508	65.3085	4	4	0.0007
Uniform	0.01528	64.4585	4	4	0.0007
Temperature and Uniform	0.01498	65.7603	4	4	0.0007

Manova for Flight Performance: Statistics-Straight & Level

Effect	Wilks' Lambda	Rao's R	df 1	df 2	p-level
Temperature	0.02868	33.8700	4	4	0.0024
Uniform	0.14188	6.0484	4	4	0.0547
Temperature and Uniform	0.19452	4.1409	4	4	0.0988

Table C-7.

Root mean squared error - Trim on and off.

MOPP0 - 70°F	Parameter							
	alt	asp	cli	hde	ral	rol	slp	trn
CONTOUR	*	*	*	3.18	49.15	3.31	0.63	*
NAP OF EARTH	*	*	*	5.33	38.78	4.88	0.72	*
HOVER	*	*	*	1.68	1.46	*	*	*
HOVER TURN	*	*	*	*	1.49	*	*	9.24
RIGHT STANDARD RATE TURN	32.17	2.31	*	*	*	3.45	*	0.52
STRAIGHT AND LEVEL	40.64	2.39	*	1.67	*	2.02	0.34	*
LEFT CLIMBING TURN	*	3.41	251.58	*	*	*	1.00	1.00
LEFT DESCENDING TURN	*	2.80	233.28	*	*	*	0.75	1.20

MOPP4 - 70°F	alt	asp	cli	hde	ral	rol	slp	trn
CONTOUR	*	*	*	3.18	50.11	2.76	0.57	*
NAP OF EARTH	*	*	*	5.60	41.08	4.61	0.71	*
HOVER	*	*	*	1.83	2.03	*	*	*
HOVER TURN	*	*	*	*	1.92	*	*	9.43
RIGHT STANDARD RATE TURN	34.70	2.31	*	*	*	3.41	*	0.53
STRAIGHT AND LEVEL	44.38	2.73	*	1.83	*	2.05	0.52	*
LEFT CLIMBING TURN	*	3.44	246.98	*	*	*	1.14	1.00
LEFT DESCENDING TURN	*	3.34	256.00	*	*	*	0.72	1.09

MOPP0 - 100°F	alt	asp	cli	hde	ral	rol	slp	trn
CONTOUR	*	*	*	3.04	46.07	2.93	0.58	*
NAP OF EARTH	*	*	*	4.15	39.42	4.81	0.71	*
HOVER	*	*	*	1.43	1.40	*	*	*
HOVER TURN	*	*	*	*	1.41	*	*	9.37
RIGHT STANDARD RATE TURN	35.80	2.27	*	*	*	3.70	*	0.64
STRAIGHT AND LEVEL	34.81	2.42	*	1.63	*	2.06	0.30	*
LEFT CLIMBING TURN	*	3.20	234.87	*	*	*	0.98	1.03
LEFT DESCENDING TURN	*	2.86	232.86	*	*	*	0.75	1.02

MOPP4 - 100°F	alt	asp	cli	hde	ral	rol	slp	trn
CONTOUR	*	*	*	5.22	49.90	3.65	0.56	*
NAP OF EARTH	*	*	*	5.29	53.29	5.01	0.67	*
HOVER	*	*	*	1.67	2.72	*	*	*
HOVER TURN	*	*	*	*	1.91	*	*	9.98
RIGHT STANDARD RATE TURN	59.72	2.85	*	*	*	4.59	*	0.77
STRAIGHT AND LEVEL	55.19	3.44	*	2.32	*	2.56	0.63	*
LEFT CLIMBING TURN	*	4.32	290.19	*	*	*	1.14	1.09
LEFT DESCENDING TURN	*	4.18	310.89	*	*	*	0.93	1.06

* Root Mean Squared Error not determined for these parameters

Table C-8.

Root mean squared error. Trim off.

MOPP0 - 70°F	Parameter						
	alt	asp	cli	hde	rol	slp	trn
RIGHT STANDARD RATE TURN	38.66	2.72	*	*	3.81	*	0.69
STRAIGHT AND LEVEL	53.53	2.91	*	1.75	2.56	0.53	*
LEFT CLIMBING TURN	*	3.91	294.97	*	*	1.16	1.00
LEFT DESCENDING TURN	*	3.34	281.06	*	*	1.34	1.22

MOPP4 - 70°F	alt	asp	cli	hde	rol	slp	trn
RIGHT STANDARD RATE TURN	43.38	2.88	*	*	3.63	*	0.59
STRAIGHT AND LEVEL	59.31	3.16	*	2.06	2.66	0.94	*
LEFT CLIMBING TURN	*	4.09	306.34	*	*	1.41	1.03
LEFT DESCENDING TURN	*	4.47	332.22	*	*	1.34	1.19

MOPP0 - 100°F	alt	asp	cli	hde	rol	slp	trn
RIGHT STANDARD RATE TURN	43.13	2.52	*	*	4.62	*	0.76
STRAIGHT AND LEVEL	43.34	2.94	*	1.66	2.69	0.47	*
LEFT CLIMBING TURN	*	3.88	290.69	*	*	1.09	1.03
LEFT DESCENDING TURN	*	3.44	293.38	*	*	1.41	1.09

MOPP4 - 100°F	alt	asp	cli	hde	rol	slp	trn
RIGHT STANDARD RATE TURN	83.31	3.88	*	*	5.06	*	0.81
STRAIGHT AND LEVEL	60.25	4.06	*	2.56	3.69	1.13	*
LEFT CLIMBING TURN	*	5.94	374.06	*	*	1.38	1.13
LEFT DESCENDING TURN	*	6.25	420.19	*	*	1.75	1.25

* Root Mean Squared Error not determined for these parameters

Table C-9.

Root mean squared error - Trim on.

MOPP0 - 70°F	Parameter alt	asp	cli	hde	ral	rol	slp	trn
CONTOUR	*	*	*	3.18	49.15	3.31	0.63	*
NAP OF EARTH	*	*	*	5.33	38.78	4.88	0.72	*
HOVER	*	*	*	1.58	1.33	*	*	*
HOVER TURN	*	*	*	*	1.50	*	*	9.33
RIGHT STANDARD RATE TURN	25.69	1.91	*	*	*	3.09	*	0.34
STRAIGHT AND LEVEL	27.75	1.88	*	1.59	*	1.47	0.16	*
LEFT CLIMBING TURN	*	2.91	208.19	*	*	*	0.84	1.00
LEFT DESCENDING TURN	*	2.25	185.50	*	*	*	0.16	1.19

MOPP4 - 70°F	alt	asp	cli	hde	ral	rol	slp	trn
CONTOUR	*	*	*	3.18	50.11	2.76	0.57	*
NAP OF EARTH	*	*	*	5.60	41.08	4.61	0.71	*
HOVER	*	*	*	1.69	2.22	*	*	*
HOVER TURN	*	*	*	*	2.00	*	*	9.39
RIGHT STANDARD RATE TURN	26.03	1.75	*	*	*	3.19	*	0.47
STRAIGHT AND LEVEL	29.44	2.31	*	1.59	*	1.44	0.09	*
LEFT CLIMBING TURN	*	2.78	187.63	*	*	*	0.88	0.97
LEFT DESCENDING TURN	*	2.22	179.78	*	*	*	0.09	1.00

MOPP0 - 100°F	alt	asp	cli	hde	ral	rol	slp	trn
CONTOUR	*	*	*	3.04	46.07	2.93	0.58	*
NAP OF EARTH	*	*	*	4.15	39.42	4.81	0.71	*
HOVER	*	*	*	1.50	1.39	*	*	*
HOVER TURN	*	*	*	*	1.33	*	*	9.36
RIGHT STANDARD RATE TURN	27.00	1.53	*	*	*	3.53	*	0.56
STRAIGHT AND LEVEL	26.28	1.91	*	1.59	*	1.44	0.13	*
LEFT CLIMBING TURN	*	2.53	177.53	*	*	*	0.88	1.03
LEFT DESCENDING TURN	*	2.28	172.34	*	*	*	0.09	0.94

MOPP4 - 100°F	alt	asp	cli	hde	ral	rol	slp	trn
CONTOUR	*	*	*	5.22	49.90	3.65	0.56	*
NAP OF EARTH	*	*	*	5.29	53.29	5.01	0.67	*
HOVER	*	*	*	1.67	2.89	*	*	*
HOVER TURN	*	*	*	*	2.28	*	*	10.22
RIGHT STANDARD RATE TURN	36.13	1.88	*	*	*	4.13	*	0.75
STRAIGHT AND LEVEL	48.13	2.81	*	2.06	*	1.69	0.19	*
LEFT CLIMBING TURN	*	2.75	214.44	*	*	*	0.88	1.06
LEFT DESCENDING TURN	*	2.25	212.06	*	*	*	0.25	0.88

* Root Mean Squared Error not determined for these parameters

Table C-10.

ANOVA results for flight performance maximums and minimums - Trim on and off.

REPEATED MEASURES ANOVA RESULTS FOR FLIGHT PERFORMANCE MINIMUMS - TRIM ON and OFF

MEAN SIMULATOR FLIGHT PERFORMANCE VALUES BY MANEUVER							MAIN EFFECTS				INTERACTION	
							TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
HOV	AVG_RADAR ALT	9	39.78	45.46	28.51	13.26	1.81	0.2160	0.17	0.6941	0.96	0.3570
HOVT	AVG_RALT	9	8.08	7.62	7.65	7.76	0.37	0.5615	0.46	0.5162	2.30	0.1676
	AVG_ROT	9	-11.08	-11.46	-11.19	-11.61	0.17	0.6945	0.69	0.4293	0.17	0.6945
RSRT	AVG_ALT	9	1946.83	1952.03	1955.92	1912.42	1.33	0.2870	2.14	0.1872	2.70	0.1444
	AVG_ROT	9	0.31	0.46	0.31	0.15	0.47	0.5123	0.00	0.9908	0.39	0.5499
	AVG_ASP	9	116.96	116.51	116.86	115.30	1.35	0.2786	6.18	0.0211	1.59	0.2425
LCT	AVG_ASP	9	113.92	113.95	114.63	112.40	1.21	0.3082	5.75	0.0476	9.26	0.0188
	AVG_ROT	9	-4.16	-4.25	-4.30	-4.74	2.27	0.1753	4.34	0.0758	0.89	0.3765
	AVG_ROC	9	-64.48	-80.70	-63.86	-96.42	0.06	0.8172	0.36	0.5652	0.09	0.7751
	AVG_SLP	9	-1.39	-1.66	-1.52	-1.77	3.05	0.1244	6.85	0.0346	0.00	0.9622
SL	AVG_ALT	9	2482.73	2487.13	2487.30	2487.35	0.18	0.6843	0.09	0.7759	0.11	0.7506
	AVG_ASP	9	116.20	115.77	116.41	113.90	8.39	0.0221	14.77	0.0063	1.54	0.2551
	AVG_ROLL	9	-4.44	-5.00	-4.05	-7.11	2.03	0.1968	20.90	0.0026	4.04	0.0842
LDT	AVG_ASP	9	115.59	115.16	116.23	113.26	0.86	0.3847	7.24	0.0310	2.00	0.2005
	AVG_ROT	9	-4.31	-4.33	-4.39	-5.19	6.62	0.0369	10.75	0.0135	3.41	0.1073
	AVG_ROC	9	-807.95	-863.50	-814.77	-938.88	4.92	0.0621	8.01	0.0284	0.70	0.4314
	AVG_SLP	9	-1.41	-1.70	-1.55	-1.89	1.33	0.2862	6.61	0.0370	0.05	0.8357
NOE	AVG_RALT	9	17.39	16.43	18.18	29.17	4.95	0.0567	1.49	0.2569	4.39	0.0693
	AVG_ROLL	9	-14.82	-14.97	-15.31	-14.53	0.00	0.9898	0.03	0.8595	0.07	0.7970
	AVG_SLP	9	-2.03	-2.01	-2.17	-1.32	1.51	0.2541	3.40	0.1023	4.20	0.0746
CONTOUR	AVG_RALT	9	31.83	35.49	32.19	37.76	0.35	0.5681	9.66	0.0146	0.07	0.7946
	AVG_ROLL	9	-12.57	-10.13	-11.96	-11.65	0.21	0.6562	2.32	0.1661	1.69	0.2304
	AVG_SLP	9	-1.90	-1.60	-2.14	-1.53	0.19	0.6742	5.35	0.0494	1.15	0.3145

REPEATED MEASURES ANOVA RESULTS FOR FLIGHT PERFORMANCE STATISTICS MAXIMUMS - TRIM ON and OFF

MEAN SIMULATOR FLIGHT PERFORMANCE VALUES BY MANEUVER							MAIN EFFECTS				INTERACTION	
							TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
HOV	AVG_RADAR ALT	9	12.43	13.43	12.21	15.54	6.45	0.0348	25.84	0.0009	4.08	0.0779
HOVT	AVG_RALT	9	12.16	12.71	12.17	13.89	1.81	0.2154	5.94	0.0408	1.57	0.2457
	AVG_ROT	9	-0.44	-0.57	-0.32	-0.69	0.00	0.9868	0.54	0.4836	0.19	0.6724
RSRT	AVG_ALT	9	2041.73	2049.09	2050.50	2058.76	1.19	0.3122	0.58	0.4713	0.00	0.9518
	AVG_ROT	9	3.91	3.78	3.98	4.00	1.41	0.2732	0.27	0.6218	0.38	0.5584
	AVG_ASP	9	124.34	124.31	124.08	125.68	1.94	0.2061	5.22	0.0562	5.51	0.0513
LCT	AVG_ASP	9	122.17	122.95	122.72	121.93	0.23	0.6456	0.00	0.9933	1.71	0.2318
	AVG_ROT	9	0.02	-0.09	0.13	-0.10	0.23	0.6478	3.61	0.0993	0.44	0.5289
	AVG_ROC	9	846.92	844.45	826.34	988.24	5.56	0.0505	11.44	0.0117	5.84	0.0463
	AVG_SLP	9	-0.08	-0.05	0.00	-0.06	0.54	0.4869	0.15	0.7110	0.34	0.5758
SL	AVG_ALT	9	2566.23	2569.03	2555.30	2588.63	0.34	0.5777	3.11	0.1211	1.67	0.2369
	AVG_ASP	9	123.11	123.08	122.72	123.24	0.07	0.7993	0.28	0.6107	0.17	0.6911
	AVG_ROLL	9	4.56	5.16	5.47	4.93	0.43	0.5340	0.00	0.9638	2.22	0.1798
	AVG_SLP	9	0.20	0.28	0.22	0.19	0.39	0.5514	0.21	0.6622	1.05	0.3398
LDT	AVG_ASP	9	123.16	123.75	123.22	122.90	0.74	0.4189	0.08	0.7868	0.61	0.4595
	AVG_ROT	9	-0.02	0.08	-0.19	-0.02	1.52	0.2579	1.34	0.2851	0.10	0.7628
	AVG_ROC	9	73.67	119.55	71.98	173.44	0.28	0.6110	5.27	0.0553	0.44	0.5290
	AVG_SLP	9	0.14	0.17	0.05	0.14	1.08	0.3326	0.58	0.4698	0.19	0.6789
NOE	AVG_RALT	9	148.22	146.10	153.14	131.07	0.53	0.4872	1.14	0.3173	2.75	0.1360
	AVG_ROLL	9	14.92	13.97	15.54	8.12	12.72	0.0073	11.97	0.0086	4.10	0.0774
	AVG_SLP	9	1.31	1.44	1.49	1.41	0.18	0.6792	0.02	0.8812	0.33	0.5841
CONTOUR	AVG_RALT	9	241.93	236.13	228.79	200.26	18.18	0.0027	3.98	0.0812	2.17	0.1788
	AVG_ROLL	9	11.79	10.11	10.22	10.03	0.53	0.4879	1.72	0.2267	0.47	0.5109
	AVG_SLP	9	1.28	1.07	1.25	1.20	0.24	0.6369	1.74	0.2236	0.94	0.3604

Table C-11.

ANOVA results for flight performance maximums and minimums - Trim on.

REPEATED MEASURES ANOVA VALUES FOR FLIGHT PERFORMANCE STATISTICS MAXIMUMS - TRIM ON

MEAN SIMULATOR FLIGHT PERFORMANCE SCORES BY MANEUVER							MAIN EFFECTS				INTERACTION	
							TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
HOV	AVG_RADAR ALT	9	330.06	300.42	300.33	359.89	2.02	0.1927	2.02	0.1927	2.58	0.1468
HOVT	AVG_RALT	9	12.00	13.03	11.89	14.78	4.30	0.0719	23.56	0.0013	3.63	0.0933
	AVG_ROT	9	-0.33	-0.53	-0.03	-0.89	0.00	0.9484	1.59	0.2424	0.67	0.4361
RSRT	AVG_ALT	9	2028.41	2026.84	2032.72	2040.06	1.23	0.3041	0.53	0.4890	0.34	0.5756
	AVG_ROT	9	3.72	3.53	3.59	3.75	0.12	0.7397	0.01	0.9262	3.32	0.1112
	AVG_ASP	9	123.69	123.78	123.34	123.75	0.17	0.6902	0.25	0.6301	0.09	0.7719
LCT	AVG_ASP	9	121.81	121.94	121.75	122.50	0.54	0.4849	0.50	0.5014	0.71	0.4260
	AVG_ROT	9	0.28	-0.13	0.19	0.00	0.01	0.9335	3.77	0.0934	0.47	0.5143
	AVG_ROC	9	776.94	737.34	722.94	862.56	0.75	0.4159	2.00	0.2000	3.13	0.1204
	AVG_SLP	9	0.03	0.03	0.03	0.00	1.00	0.3506	1.00	0.3506	0.18	0.6845
SL	AVG_ALT	9	2545.03	2544.47	2541.50	2570.50	1.52	0.2568	1.85	0.2158	2.03	0.1968
	AVG_ASP	9	122.16	121.75	121.53	122.44	0.00	0.9625	0.25	0.6024	0.64	0.4500
	AVG_ROLL	9	3.44	4.13	4.34	3.81	0.13	0.7276	0.01	0.9319	0.52	0.4934
	AVG_SLP	9	0.28	0.31	0.31	0.00	7.99	0.0256	5.50	0.0514	8.92	0.0203
LDT	AVG_ASP	9	121.91	121.84	121.69	122.19	0.14	0.7220	0.26	0.6278	0.29	0.6051
	AVG_ROT	9	0.00	-0.16	-0.06	-0.13	0.01	0.9269	0.43	0.5313	0.07	0.7984
	AVG_ROC	9	3.34	-37.03	-46.50	12.50	0.00	0.9951	0.17	0.6890	4.84	0.0638
	AVG_SLP	9	0.31	0.16	0.19	0.19	0.57	0.4758	0.50	0.5029	0.92	0.3703
NOE	AVG_RALT	9	148.22	146.10	153.14	131.07	0.53	0.4872	1.14	0.3173	2.75	0.1360
	AVG_ROLL	9	14.92	13.97	15.54	8.12	12.72	0.0073	11.97	0.0068	4.10	0.0774
	AVG_SLP	9	1.31	1.44	1.49	1.41	0.18	0.6792	0.02	0.8812	0.33	0.5841
CONTOUR	AVG_HDG	9	162.19	150.76	155.78	152.18	0.17	0.6932	0.95	0.3586	0.84	0.3864
	AVG_RALT	9	241.93	236.13	228.79	200.26	18.18	0.0027	3.98	0.0812	2.17	0.1788
	AVG_ROLL	9	11.79	10.11	10.22	10.03	0.53	0.4879	1.72	0.2267	0.47	0.5109
	AVG_SLP	9	1.26	1.07	1.25	1.20	0.24	0.6369	1.74	0.2236	0.94	0.3604

REPEATED MEASURES ANOVA RESULTS FOR FLIGHT PERFORMANCE MINIMUMS- TRIM ON

MEAN SIMULATOR FLIGHT PERFORMANCE VALUES BY MANEUVER							MAIN EFFECTS				INTERACTION	
							TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
HOV	AVG_RADAR ALT	9	49.69	19.94	20.11	19.89	0.66	0.4398	0.40	0.5434	0.96	0.35
HOVT	AVG_RALT	9	7.94	7.56	7.58	7.94	0.00	0.9486	0.00	0.9666	2.49	0.15
	AVG_ROT	9	-11.75	-11.50	-11.22	-11.83	0.05	0.8333	0.10	0.7628	1.00	0.35
RSRT	AVG_ALT	9	1933.41	1946.22	1954.19	1872.06	1.01	0.3487	1.58	0.2497	3.01	0.13
	AVG_ROT	9	0.31	0.50	0.23	-0.44	1.78	0.2237	0.56	0.4774	1.33	0.29
	AVG_ASP	9	116.41	115.50	115.79	113.44	2.63	0.1489	8.66	0.0206	0.58	0.47
LCT	AVG_ASP	9	112.69	112.75	113.66	110.38	0.97	0.3568	3.94	0.0675	4.54	0.07
	AVG_ROT	9	-4.44	-4.31	-4.59	-5.06	3.78	0.0938	0.41	0.5421	0.82	0.39
	AVG_ROC	9	-135.31	-181.63	-161.22	-287.44	1.84	0.2410	2.08	0.1944	0.56	0.48
	AVG_SLP	9	-1.78	-2.31	-2.00	-2.38	1.09	0.3307	7.84	0.0265	0.12	0.74
SL	AVG_ALT	9	2479.00	2489.72	2484.03	2484.03	0.00	0.9552	2.19	0.1773	2.19	0.18
	AVG_ASP	9	115.78	115.66	116.41	113.13	2.62	0.1497	4.54	0.0705	1.11	0.33
	AVG_ROLL	9	-6.03	-6.84	-6.13	-10.38	3.20	0.1168	5.07	0.0590	1.42	0.27
	AVG_SLP	9	-1.09	-1.44	-1.06	-1.88	0.50	0.5024	9.52	0.0177	2.12	0.19
LDT	AVG_ASP	9	114.66	113.69	115.72	110.31	0.48	0.5121	5.06	0.0592	1.19	0.31
	AVG_ROT	9	-4.44	-4.81	-4.88	-6.06	7.74	0.0272	8.91	0.0204	1.50	0.26
	AVG_ROC	9	-905.22	-998.22	-915.03	-1047.19	1.08	0.3325	7.25	0.0310	0.12	0.74
	AVG_SLP	9	-2.06	-2.53	-2.41	-2.94	3.36	0.1095	6.31	0.0403	0.03	0.87
NOE	AVG_RALT	9	17.39	16.43	18.18	29.17	4.95	0.0567	1.49	0.2569	4.39	0.07
	AVG_ROLL	9	-14.82	-14.97	-15.31	-14.53	0.00	0.9898	0.03	0.8595	0.07	0.80
	AVG_SLP	9	-2.03	-2.01	-2.17	-1.32	1.51	0.2541	3.40	0.1023	4.20	0.07
CONTOUR	AVG_RALT	9	31.83	35.49	32.19	37.76	0.35	0.5681	8.66	0.0148	0.07	0.79
	AVG_ROLL	9	-12.57	-10.13	-11.96	-11.65	0.21	0.6562	2.32	0.1661	1.69	0.23
	AVG_SLP	9	-1.90	-1.60	-2.14	-1.53	0.19	0.6742	5.35	0.0494	1.15	0.31

Table C-12.

ANOVA results for flight performance maximums and minimums - Trim off.

REPEATED MEASURES ANOVA RESULTS FOR FLIGHT PERFORMANCE STATISTICS MAXIMUMS - TRIM OFF

MEAN SIMULATOR FLIGHT PERFORMANCE VALUES BY MANEUVER							MAIN EFFECTS TEMPERATURE		MAIN EFFECTS UNIFORM		INTERACTION TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
RSRT	AVG_ALT	9	2055.06	2071.34	2073.79	2079.25	0.82	0.3985	0.30	0.6036	0.29	0.6051
	AVG_ROT	9	4.09	4.03	3.96	4.25	0.17	0.6942	6.16	0.0421	2.34	0.1702
	AVG_ASP	9	125.00	124.84	124.01	127.81	1.79	0.2222	6.73	0.0357	14.43	0.0057
LCT	AVG_ASP	9	122.53	124.16	123.69	121.50	0.36	0.5699	0.08	0.7867	3.94	0.0874
	AVG_ROT	9	-0.25	-0.06	0.03	-0.25	0.36	0.5674	0.06	0.8066	2.08	0.1929
	AVG_ROC	9	916.91	951.56	929.75	1122.69	8.74	0.0212	34.91	0.0006	4.07	0.0834
	AVG_SLP	9	-0.16	-0.19	-0.13	-0.13	0.25	0.6344	0.05	0.8264	0.01	0.9346
SL	AVG_ALT	9	2587.44	2593.59	2589.09	2603.75	0.51	0.4972	3.48	0.1045	0.37	0.5637
	AVG_ASP	9	124.06	124.41	123.91	124.13	0.25	0.6308	0.13	0.7283	0.01	0.9365
	AVG_ROLL	9	5.69	6.19	6.59	6.44	1.03	0.3445	0.02	0.8789	0.10	0.7604
	AVG_SLP	9	0.13	0.19	0.13	0.38	0.61	0.4598	1.58	0.2495	1.62	0.2443
LDT	AVG_ASP	9	124.41	125.56	124.75	124.06	0.33	0.5814	0.06	0.8073	0.86	0.3836
	AVG_ROT	9	-0.03	0.31	-0.16	0.00	1.54	0.2549	1.33	0.2861	0.15	0.7136
	AVG_ROC	9	144.00	276.13	190.47	376.25	0.88	0.3794	8.49	0.0225	0.13	0.7282
	AVG_SLP	9	-0.03	0.19	-0.09	0.00	1.00	0.3506	0.81	0.3969	0.20	0.6682

REPEATED MEASURES ANOVA RESULTS FOR FLIGHT PERFORMANCE MINIMUMS - TRIM OFF

MEAN SIMULATOR FLIGHT PERFORMANCE VALUES BY MANEUVER							MAIN EFFECTS TEMPERATURE		MAIN EFFECTS UNIFORM		INTERACTION TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
RSRT	AVG_ALT	9	1933.41	1946.22	1954.19	1872.06	1.01	0.3487	1.58	0.2497	3.01	0.1265
	AVG_ROT	9	0.31	0.50	0.23	-0.44	1.78	0.2237	0.56	0.4774	1.33	0.2873
	AVG_ASP	9	116.41	115.50	115.79	113.44	2.63	0.1489	8.88	0.0205	0.58	0.4727
LCT	AVG_ASP	9	112.69	112.75	113.66	110.38	0.97	0.3566	3.94	0.0875	4.54	0.0706
	AVG_ROT	9	-4.44	-4.31	-4.59	-5.06	3.76	0.0938	0.41	0.5421	0.82	0.3945
	AVG_ROC	9	-135.31	-161.63	-161.22	-287.44	1.64	0.2410	2.06	0.1944	2.06	0.1944
	AVG_SLP	9	-1.78	-2.31	-2.00	-2.38	1.09	0.3307	7.84	0.0265	0.12	0.7403
SL	AVG_ALT	9	2479.00	2489.72	2484.03	2484.03	0.00	0.9552	2.19	0.1773	2.19	0.1773
	AVG_ASP	9	115.78	115.66	116.41	113.13	2.62	0.1497	4.54	0.0705	1.11	0.3270
	AVG_ROLL	9	-6.03	-6.94	-6.13	-10.38	3.20	0.1168	5.07	0.0590	1.42	0.2729
	AVG_SLP	9	-1.09	-1.44	-1.06	-1.88	0.50	0.5024	9.52	0.0177	2.12	0.1887
LDT	AVG_ASP	9	114.66	113.69	115.72	110.31	0.48	0.5121	5.06	0.0592	1.19	0.3113
	AVG_ROT	9	-4.44	-4.81	-4.88	-6.06	7.74	0.0272	8.91	0.0204	1.50	0.2598
	AVG_ROC	9	-905.22	-996.22	-915.03	-1047.19	1.08	0.3325	7.25	0.0310	0.12	0.7419
	AVG_SLP	9	-2.06	-2.53	-2.41	-2.94	3.36	0.1095	6.31	0.0403	0.03	0.8679

Table C-13.

Repeated measures ANOVA results for flight performance statistics - Trim on and off.

AVERAGES AND STANDARD DEVIATIONS OF SIMULATOR FLIGHT PERFORMANCE PARAMETERS BY MANEUVER							MAIN EFFECTS				INTERACTION	
							TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
HOV	AVG_ALT	9	194.79	169.11	175.25	192.56	0.02	0.8988	0.94	0.3615	1.18	0.3092
	STD ALT	9	133.38	114.14	115.38	148.37	0.97	0.3543	1.00	0.3474	6.76	**0.0317**
	AVG HEADING	9	9.86	9.86	9.95	10.59	7.08	**0.0287**	2.59	0.1463	2.07	0.1880
	STD HEADING	9	0.60	1.10	0.48	1.59	3.97	0.0814	25.68	**0.0010**	3.87	0.0849
HOVT	AVG_RALT	9	9.78	9.68	9.63	10.48	3.81	0.0866	8.31	**0.0204**	4.61	0.0642
	STD_RALT	9	1.03	1.37	1.08	1.65	0.91	0.3693	5.41	0.0484	0.59	0.4635
	AVG_ROT	9	-6.06	-6.21	-6.08	-6.72	2.77	0.1348	7.47	**0.0257**	2.91	0.1263
	STD_ROT	9	2.40	2.46	2.49	2.50	0.88	0.3757	0.10	0.7597	0.07	0.8027
RSRT	AVG_ALT	9	1998.31	2003.97	2004.09	1983.10	0.56	0.4804	0.70	0.4310	2.06	0.1939
	STD_ALT	9	25.70	25.50	25.55	40.70	14.39	**0.0065**	7.48	**0.0291**	5.35	0.0540
	AVG_ROT	9	3.00	3.00	3.00	3.06	1.00	0.3466	1.00	0.3466	1.00	0.3466
	STD_ROT	9	0.56	0.67	0.69	0.71	1.59	0.2477	0.45	0.5244	0.24	0.6378
	AVG_ASP	9	120.69	120.56	120.56	120.24	0.42	0.5370	1.05	0.3399	0.20	0.6664
	STD_ASP	9	1.75	1.84	1.81	2.63	17.59	**0.0041**	8.37	**0.0232**	4.81	0.0644
LCT	AVG_ASP	9	117.97	118.53	118.67	117.01	1.12	0.3256	1.30	0.2921	5.46	0.0521
	STD_ASP	9	2.19	2.47	2.03	2.56	0.06	0.8176	4.45	0.0729	1.20	0.3088
	AVG_ROT	9	-2.88	-2.81	-2.84	-3.05	4.55	0.0705	2.27	0.1755	3.26	0.1132
	STD_ROT	9	1.05	0.98	1.05	1.19	1.02	0.3454	0.55	0.4839	7.67	**0.0277**
	AVG_ROC	9	450.23	447.14	448.03	471.41	1.68	0.2354	1.79	0.2228	0.97	0.3564
	STD_ROC	9	224.97	221.47	143.92	258.50	1.71	0.2318	4.31	0.0765	4.44	0.0731
	AVG_SLP	9	-0.91	-1.05	-0.89	-1.01	0.14	0.7160	3.45	0.1055	0.02	0.9014
	STD_SLP	9	0.00	0.00	0.03	0.06	2.03	0.1970	0.18	0.6845	0.18	0.6845
SL	AVG_HDG	9	164.28	173.19	175.20	95.33	53.59	**0.0002**	51.54	**0.0002**	86.50	**0.0000**
	STD_HDG	9	15.73	18.69	14.80	1.93	6.27	**0.0407**	18.56	**0.0035**	8.16	**0.0244**
	AVG_ALT	9	2521.36	2529.22	2520.94	2540.05	0.69	0.4335	1.78	0.2238	0.75	0.4166
	STD_ALT	9	24.16	24.00	19.95	30.11	1.36	0.2818	9.56	**0.0175**	1.51	0.2584
	AVG_ASP	9	120.11	119.67	120.05	119.48	0.15	0.7084	6.65	**0.0368**	0.02	0.8869
	STD_ASP	9	1.97	1.98	1.75	2.75	2.23	0.1787	3.62	0.0988	1.51	0.2586
	AVG_ROLL	9	-0.19	-0.30	-0.23	-0.67	4.50	0.0715	6.59	**0.0372**	3.29	0.1128
	STD_ROLL	9	1.94	1.98	1.94	2.33	1.16	0.3177	3.11	0.1211	2.16	0.1855
LDT	AVG_ASP	9	119.53	119.59	119.72	118.76	0.52	0.4932	0.59	0.4682	0.76	0.4130
	STD_ASP	9	2.13	2.42	2.02	2.85	0.88	0.3793	30.59	0.0009	0.80	0.4012
	AVG_ROT	9	-2.69	-2.69	-2.86	-2.83	5.19	0.0569	0.08	0.7856	0.04	0.8552
	STD_ROT	9	1.08	1.09	1.03	1.00	2.16	0.1855	0.01	0.9094	0.57	0.4758
	AVG_ROC	9	-428.28	-436.61	-439.20	-449.94	1.14	0.3208	1.26	0.2988	0.00	0.9524
	STD_ROC	9	213.73	241.33	219.77	294.34	2.97	0.1283	12.44	0.0096	1.09	0.3322
	AVG_SLP	9	-0.64	-0.64	-0.64	-0.83	0.84	0.3895	0.56	0.4791	0.95	0.3613
	STD_SLP	9	0.19	0.33	0.19	0.28	0.17	0.6910	4.20	0.0796	0.12	0.7397
NOE	AVG_HDG	9	239.35	237.71	239.47	228.85	1.06	0.3337	2.02	0.1929	1.21	0.3039
	STD_HDG	9	6.79	6.44	3.32	2.93	4.29	0.0720	0.21	0.6586	0.00	0.9770
	AVG_RALT	9	51.60	54.21	51.36	70.23	2.89	0.1273	2.71	0.1385	4.71	0.0617
	STD_RALT	9	26.19	27.14	26.86	26.16	0.01	0.9199	0.00	0.9652	0.21	0.6559
	AVG_ROLL	9	-0.22	-0.36	-0.21	-0.69	0.27	0.6168	0.85	0.3829	0.34	0.5779
	STD_ROLL	9	4.86	4.60	4.85	4.84	0.08	0.7893	0.08	0.7831	0.04	0.8488
	AVG_SLP	9	-0.13	-0.11	-0.10	-0.03	0.76	0.4088	1.23	0.2995	0.21	0.6601
	STD_SLP	9	0.57	0.54	0.60	0.53	0.01	0.9411	0.30	0.5968	0.11	0.7475
CONTOUR	AVG_HDG	9	115.39	112.58	109.18	142.64	14.25	**0.0054**	51.61	0.0001	42.45	0.0002
	STD_HDG	9	18.47	15.50	12.71	3.93	19.05	**0.0024**	15.24	0.0045	3.23	0.1100
	AVG_RALT	9	97.96	100.51	96.93	103.74	0.16	0.7003	2.05	0.1900	0.41	0.5377
	STD_RALT	9	42.78	41.97	40.03	38.79	1.99	0.1962	0.32	0.5861	0.01	0.9316
	AVG_ROLL	9	-0.24	-0.22	-0.26	-0.16	0.04	0.8417	0.90	0.3710	0.17	0.6876
	STD_ROLL	9	3.26	2.78	2.93	3.72	0.85	0.3829	0.70	0.4262	3.55	0.0963
	AVG_SLP	9	-0.04	-0.03	-0.14	-0.03	0.44	0.5274	0.67	0.4356	0.45	0.5219
	STD_SLP	9	0.42	0.31	0.42	0.41	4.86	0.0582	0.53	0.4876	0.67	0.4361

Table C-14.

Repeated measures ANOVA results for flight performance statistics - Trim on.

AVERAGES AND STANDARD DEVIATIONS OF SIMULATOR FLIGHT PERFORMANCE PARAMETERS BY MANEUVER							MAIN EFFECTS				INTERACTION	
							TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
HOV	AVG_ALT	9	180.83	143.50	178.69	192.61	0.78	0.4042	0.51	0.4940	1.04	0.3371
	STD ALT	9	133.38	114.14	115.38	148.37	0.97	0.3543	1.00	0.3474	6.76	**0.0317**
	AVG HEADING	9	9.81	10.06	9.89	10.44	0.78	0.4040	2.77	0.1344	0.22	0.6491
	STD HEADING	9	0.60	1.10	0.48	1.59	3.97	0.0814	25.68	**0.0010**	3.87	0.0849
HOVT	AVG_RALT	9	9.69	9.86	9.61	10.67	2.40	0.1603	19.81	**0.0021**	6.88	**0.0305**
	STD_RALT	9	1.03	1.37	1.08	1.65	0.91	0.3693	5.41	0.0484	0.59	0.4635
	AVG_ROT	9	-6.14	-6.19	-6.03	-6.83	3.31	0.1063	9.07	**0.0168**	5.23	0.0516
	STD_ROT	9	2.40	2.46	2.49	2.50	0.88	0.3757	0.10	0.7597	0.07	0.8027
RSRT	AVG_ALT	9	1996.78	1995.75	1998.72	1998.56	0.16	0.6985	0.03	0.8585	0.01	0.9377
	STD_ALT	9	17.81	18.31	19.16	24.75	73.77	1.6414	43.81	1.6951	53.17	0.9760
	STD_ROT	9	0.41	0.53	0.59	0.63	1.82	0.2190	0.38	0.5581	0.28	0.6115
	AVG_ASP	9	120.81	120.75	120.38	120.31	1.83	0.2177	0.11	0.7524	0.00	1.0000
	STD_ASP	9	1.34	1.38	1.22	1.63	0.18	0.6807	2.79	0.1389	1.66	0.2388
LCT	AVG_ASP	9	118.41	118.44	118.69	118.31	0.06	0.8118	0.24	0.6409	0.28	0.6117
	STD_ASP	9	2.03	1.91	1.63	2.13	0.53	0.4905	0.57	0.4758	3.18	0.1176
	AVG_ROT	9	-2.88	-2.94	-2.97	-3.00	0.78	0.4051	0.26	0.6235	0.02	0.9031
	STD_ROT	9	1.03	0.97	1.03	1.13	0.61	0.4605	0.13	0.7318	5.65	0.0492
	AVG_ROC	9	447.81	457.38	444.97	480.94	0.61	0.4619	2.16	0.1847	0.54	0.4867
	STD_ROC	9	195.31	177.25	97.59	197.00	9.68	**0.0170**	1.71	0.2321	3.98	0.0863
	AVG_SLP	9	-0.72	-0.75	-0.41	-0.75	3.72	0.0950	2.17	0.1840	1.22	0.3052
SL	AVG_HDG	9	148.75	165.97	170.78	89.69	12.49	**0.0096**	12.71	**0.0092**	25.09	**0.0015**
	STD_HDG	9	29.91	34.88	28.28	1.56	6.17	**0.0420**	19.04	**0.0033**	8.23	**0.0240**
	AVG_ALT	9	2515.22	2513.38	2515.47	2540.00	3.75	0.0941	1.88	0.2122	1.82	0.2199
	STD_ALT	9	16.19	17.91	15.50	19.00	0.01	0.9075	1.83	0.2180	0.39	0.5507
	AVG_ASP	9	119.81	119.31	119.47	119.75	0.01	0.9247	0.11	0.7550	0.70	0.4309
	STD_ASP	9	1.53	1.56	1.47	2.00	0.72	0.4229	1.37	0.2807	0.78	0.4071
	AVG_ROLL	9	0.13	0.06	0.16	-0.38	3.53	0.1023	2.68	0.1456	2.94	0.1299
	STD_ROLL	9	1.31	1.41	1.31	2.00	5.28	0.0552	2.59	0.1513	2.32	0.1712
	AVG_SLP	9	-0.03	-0.03	-0.03	-0.19	1.38	0.2788	0.39	0.5514	1.38	0.2788
LDT	AVG_ASP	9	119.25	119.28	119.19	120.06	1.37	0.2795	1.12	0.3254	0.90	0.3741
	STD_ASP	9	1.50	1.41	1.47	1.75	1.34	0.2857	0.28	0.6146	0.45	0.5238
	AVG_ROT	9	-2.66	-2.81	-2.88	-2.88	2.16	0.1855	0.42	0.5368	0.61	0.4605
	STD_ROT	9	1.06	1.00	0.97	0.75	4.43	0.0732	1.58	0.2492	0.39	0.5514
	AVG_ROC	9	-424.97	-445.97	-448.03	-467.25	2.41	0.1642	2.31	0.1722	0.00	0.9643
	STD_ROC	9	165.09	173.91	158.72	200.81	0.39	0.5525	3.42	0.1068	0.78	0.4078
	AVG_SLP	9	-0.06	-0.09	-0.03	-0.19	0.37	0.5630	1.47	0.2654	0.58	0.4700
NOE	AVG_HDG	9	239.35	237.71	239.51	234.00	0.10	0.7652	0.39	0.5520	0.12	0.7398
	STD_HDG	9	6.79	6.44	3.32	2.93	4.29	0.0720	0.21	0.6586	0.00	0.9770
	AVG_RALT	9	51.60	54.21	51.36	70.23	2.89	0.1273	2.71	0.1385	4.71	0.0617
	STD_RALT	9	26.19	27.14	26.86	26.16	0.01	0.9199	0.00	0.9652	0.21	0.6559
	AVG_ROLL	9	-0.22	-0.38	-0.20	-0.92	0.85	0.3826	1.76	0.2208	1.03	0.3410
	STD_ROLL	9	4.86	4.56	4.85	4.84	0.10	0.7546	0.12	0.7428	0.05	0.8293
	AVG_SLP	9	-0.22	-0.38	-0.20	-0.92	0.76	0.4088	1.23	0.2995	0.21	0.6601
	STD_SLP	9	0.58	0.54	0.60	0.53	0.00	1.0000	0.41	0.5401	0.05	0.8268
CONTOUR	AVG_HDG	9	115.39	112.58	109.18	142.64	14.25	**0.0054**	51.61	**0.0001**	42.45	**0.0002**
	STD_HDG	9	18.47	15.50	12.71	3.93	19.05	**0.0024**	15.24	**0.0045**	3.23	0.1100
	AVG_RALT	9	97.96	100.76	96.93	103.74	0.12	0.7371	2.21	0.1758	0.37	0.5612
	STD_RALT	9	42.78	41.97	40.03	38.79	1.99	0.1962	0.32	0.5861	0.01	0.9316
	AVG_ROLL	9	-0.24	-0.22	-0.26	-0.16	0.04	0.8417	0.90	0.3710	0.17	0.6876
	STD_ROLL	9	3.26	2.78	2.93	3.72	0.85	0.3829	0.70	0.4262	3.55	0.0963
	AVG_SLP	9	-0.04	-0.03	-0.21	-0.03	2.13	0.1830	0.92	0.3652	0.62	0.4528
	STD_SLP	9	0.42	0.29	0.42	0.41	5.58	**0.0458**	0.70	0.4278	0.85	0.3828

Table C-15.

Repeated measures ANOVA results for flight performance statistics - Trim off.

AVERAGES AND STANDARD DEVIATIONS OF SIMULATOR FLIGHT PERFORMANCE PARAMETERS BY MANEUVER							MAIN EFFECTS				INTERACTION	
							TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
MANEUVER	PARAMETER	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
RSRT	AVG_ALT	9	1999.84	2012.19	2014.29	1971.69	0.47	0.5166	0.64	0.4508	2.90	0.1323
	STD_ALT	9	33.59	32.69	32.47	56.88	7.07	**0.0326**	3.82	0.0917	3.65	0.0978
	AVG_ROT	9	3.00	3.00	2.85	3.13	0.01	0.9079	2.31	0.1725	2.31	0.1725
	STD_ROT	9	0.72	0.81	0.73	0.81	0.00	0.9676	1.55	0.2537	0.00	0.9760
	AVG_ASP	9	120.31	120.38	120.12	120.19	0.24	0.6410	0.04	0.8505	0.00	0.9948
	STD_ASP	9	2.16	2.31	2.07	3.63	6.98	**0.0333**	17.51	**0.0041**	7.05	**0.0327**
LCT	AVG_ASP	9	117.53	118.63	118.66	115.69	1.18	0.3140	1.14	0.3202	9.47	**0.0179**
	STD_ASP	9	2.66	3.00	2.75	3.31	0.66	0.4431	7.08	**0.0324**	0.12	0.7384
	AVG_ROT	9	-2.88	-2.69	-2.72	-3.13	3.75	0.0938	2.88	0.1334	5.65	**0.0491**
	STD_ROT	9	0.97	1.00	1.03	1.13	2.33	0.1705	0.88	0.3807	0.20	0.6682
	AVG_ROC	9	452.66	436.91	451.09	455.31	0.26	0.6246	0.18	0.6856	0.71	0.4278
	STD_ROC	9	337.66	295.84	281.34	366.25	0.04	0.8400	0.81	0.3993	5.20	0.0567
	AVG_SLP	9	-1.09	-1.34	-1.06	-1.25	0.19	0.6725	2.33	0.1705	0.04	0.8551
	STD_SLP	9	0.09	0.38	0.25	0.50	1.34	0.2849	5.90	**0.0458**	0.01	0.9094
SL	AVG_HDG	9	179.81	180.41	179.63	100.94	51.66	**0.0002**	47.98	**0.0002**	48.40	**0.0002**
	STD_HDG	9	1.56	1.75	1.31	2.31	1.58	0.2495	15.89	**0.0053**	6.46	**0.0385**
	AVG_ALT	9	2527.50	2545.06	2526.41	2538.00	0.33	0.5858	1.31	0.2903	0.14	0.7191
	STD_ALT	9	32.13	30.09	24.41	41.06	0.68	0.4361	5.74	**0.0477**	1.17	0.3156
	AVG_ASP	9	120.41	120.03	120.63	119.31	0.75	0.4162	10.31	**0.0148**	0.65	0.4486
	STD_ASP	9	2.41	2.41	2.03	3.50	3.07	0.1233	2.61	0.1503	1.35	0.2829
	AVG_ROLL	9	-0.50	-0.66	-0.63	-1.06	1.18	0.3139	4.80	0.0647	1.92	0.2082
	STD_ROLL	9	2.56	2.56	2.56	3.38	4.43	0.0733	1.77	0.2247	1.14	0.3205
	AVG_SLP	9	-0.31	-0.66	-0.38	-0.63	0.01	0.9351	4.06	0.0839	0.10	0.7655
	STD_SLP	9	0.09	0.16	0.06	0.38	0.94	0.3645	2.86	0.1344	1.47	0.2641
LDT	AVG_ASP	9	119.81	119.91	120.25	117.75	0.60	0.4633	1.24	0.3031	0.87	0.3829
	STD_ASP	9	2.75	3.44	2.44	4.06	0.27	0.6212	19.36	**0.0032**	0.85	0.3875
	AVG_ROT	9	-2.72	-2.56	-2.84	-2.75	2.78	0.1395	4.67	0.0676	0.10	0.7627
	STD_ROT	9	1.09	1.19	1.09	1.25	0.11	0.7486	1.75	0.2275	0.11	0.7486
	AVG_ROC	9	-431.59	-427.25	-430.38	-427.06	0.00	0.9729	0.06	0.8203	0.00	0.9865
	STD_ROC	9	262.38	319.41	280.81	397.88	2.25	0.1772	15.25	**0.0059**	0.57	0.4759
	AVG_SLP	9	-1.22	-1.19	-1.25	-1.63	1.30	0.2909	0.55	0.4618	1.40	0.2759
	STD_SLP	9	0.38	0.66	0.38	0.56	0.17	0.6910	4.20	0.0796	0.12	0.7397

Table C-16.

Repeated measures ANOVA results for simulator incidents.

		MEAN SIMULATOR INCIDENTS BY CONDITION				MAIN EFFECTS				INTERACTION	
						TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
EVENT	NUM TSs	ABDU, 70°F	MOPP IV,70°F	ABDU, 100°F	MOPP IV, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
Total Simulator Flight Time	9	249.78	243.56	238.44	64.44	379.22	0.0000	256.66	0.0000	194.81	0.0000
Air Assault	9	121.11	119.89	119.67	64.44	39.74	0.0002	45.44	0.0001	37.08	0.0003
MedEvac	9	123.44	123.67	229.89	0.00	0.02	0.8821	4.37	0.0699	4.22	0.0741
Crash											
rotor strike	9	0.00	0.00	0.44	0.00	3.37	0.1038	3.37	0.1038	3.37	0.1038
stabilator strike	9	0.89	0.89	0.44	0.11	4.57	0.0651	0.50	0.4996	0.33	0.5796
during hover	9	0.00	0.00	0.00	0.00	--	--	--	--	--	--
attempting to land	9	0.00	0.11	0.00	0.22	1.00	0.3466	2.00	0.1950	1.00	0.3466
flew into terrain	9	0.67	0.00	0.44	0.00	0.31	0.5943	6.90	0.0304	0.31	0.5943
loss of control at alt	9	0.22	0.00	0.00	0.11	0.31	0.5943	0.31	0.5943	4.00	0.0805
other	9	0.22	0.22	0.00	0.22	0.64	0.4468	0.37	0.5588	0.64	0.4468
Sub Total	9	2.00	1.78	1.33	0.67	2.93	0.1251	0.38	0.5563	0.18	0.6848
Average	9	0.29	0.25	0.19	0.10	2.93	0.1251	0.38	0.5563	0.18	0.6849

Table C-17.

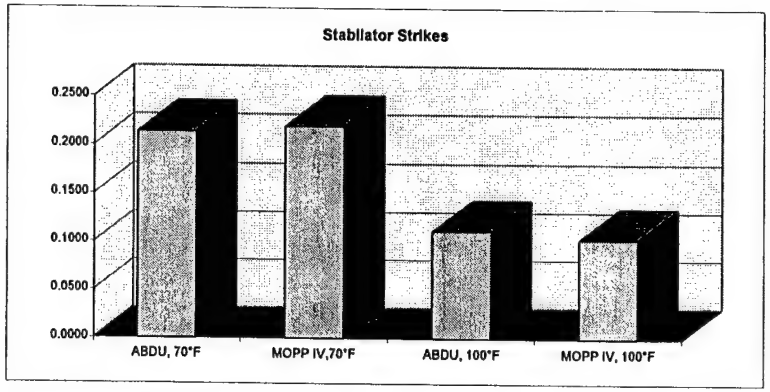
Repeated measures ANOVA results for simulator incidents per hour.

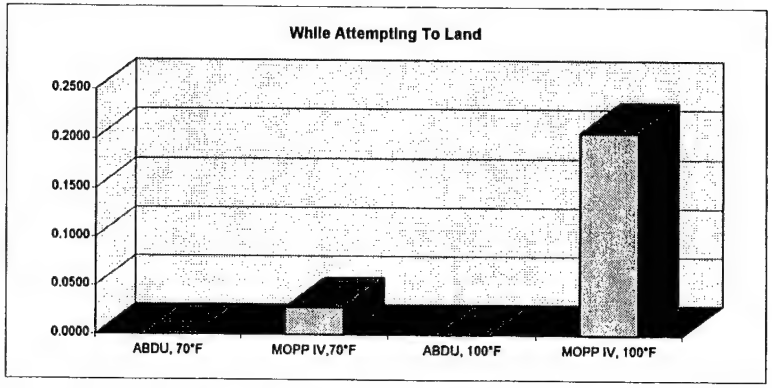
		MEAN SIMULATOR INCIDENTS BY CONDITION				MAIN EFFECTS				INTERACTION	
						TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
EVENT	NUM TSs	ABDU, 70°F	MOPP IV,70°F	ABDU, 100°F	MOPP IV, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
Total Simulator Flight Time	9	249.78	243.56	238.44	64.44	379.22	0.0000	256.66	0.0000	194.81	0.0000
Air Assault	9	121.11	119.89	119.67	64.44	39.74	0.0002	45.44	0.0001	37.08	0.0003
MedEvac	9	123.44	123.67	229.89	0.00	0.02	0.8821	4.37	0.0699	4.22	0.0741
Crash											
rotor strike	9	0.00	0.00	0.11	0.00	3.46	0.0998	3.46	0.0998	3.46	0.0998
stabilator strike	9	0.21	0.22	0.11	0.12	1.10	0.3250	0.01	0.9323	0.00	0.9939
during hover	9	0.00	0.00	0.00	0.00	-	-	-	-	-	-
attempting to land	9	0.00	0.03	0.00	0.26	2.19	0.1771	2.28	0.1695	2.19	0.1771
flew into terrain	9	0.16	0.00	0.11	0.00	0.28	0.6098	7.14	0.0283	0.28	0.6098
loss of control at alt	9	0.05	0.00	0.00	0.20	0.49	0.5035	0.49	0.5035	1.66	0.2333
other	9	0.05	0.05	0.00	0.27	0.79	0.3994	1.58	0.2445	2.60	0.1452
Sub Total	9	0.47	0.43	0.33	0.85	0.67	0.4370	0.58	0.4680	2.18	0.1782
Average	9	0.07	0.06	0.05	0.12	0.67	0.4368	0.58	0.4679	2.18	0.1781

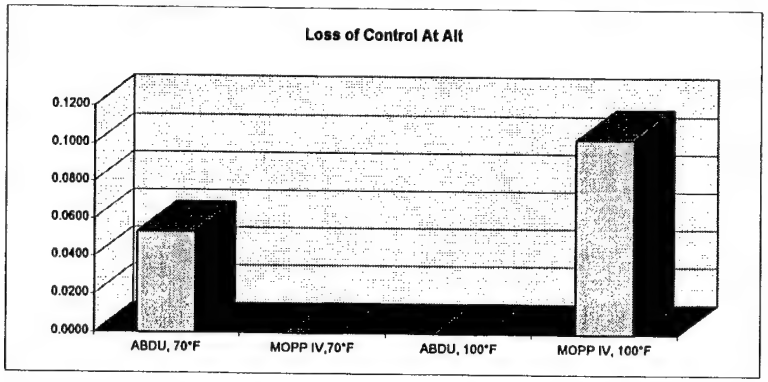
Appendix D. Flight performance charts.

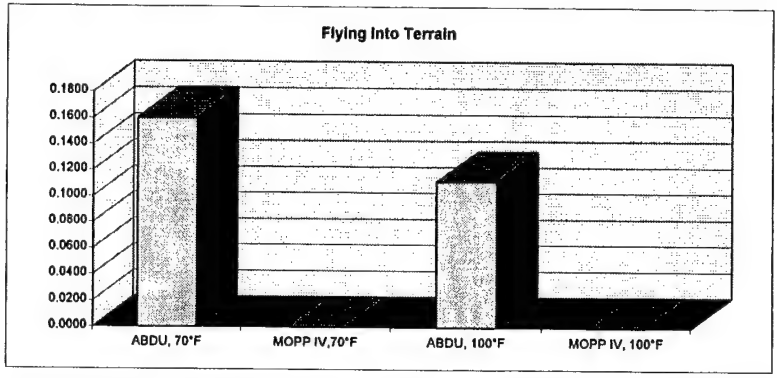
Table D-1.

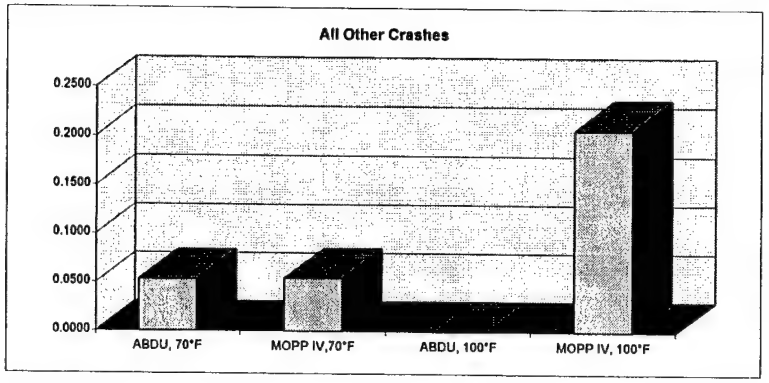
Time weighted simulator incident rates.











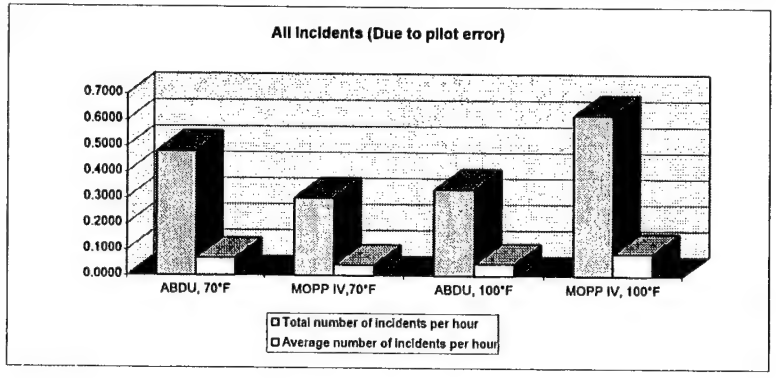
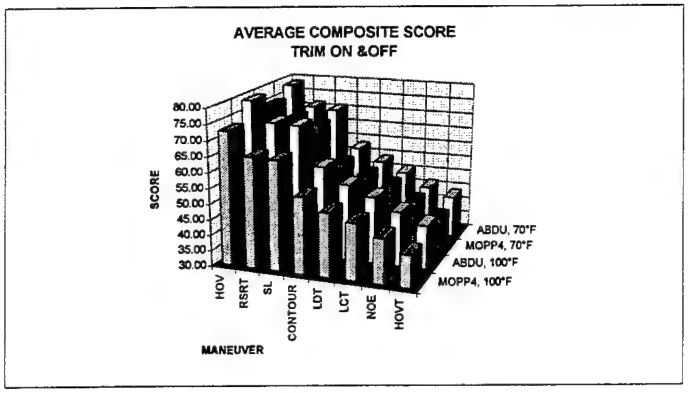
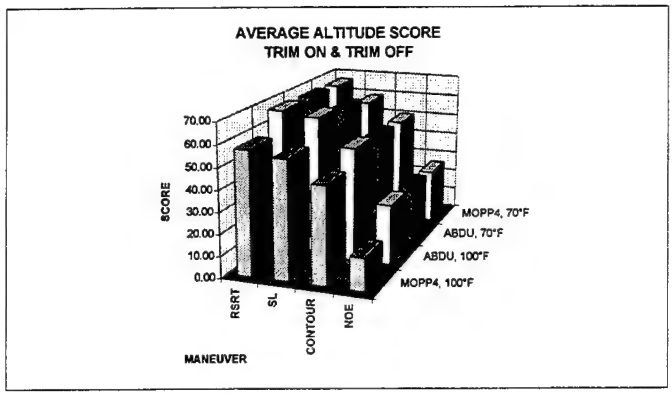
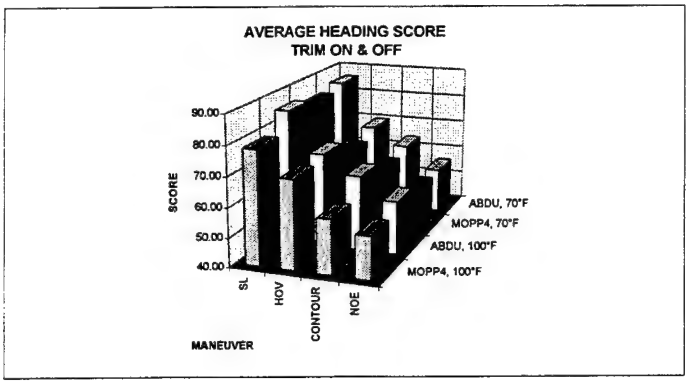


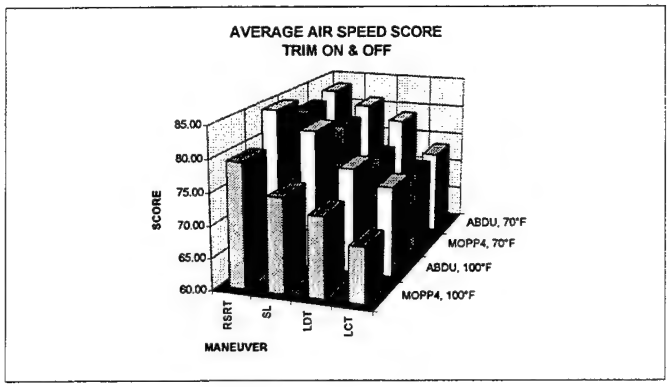
Table D-2.

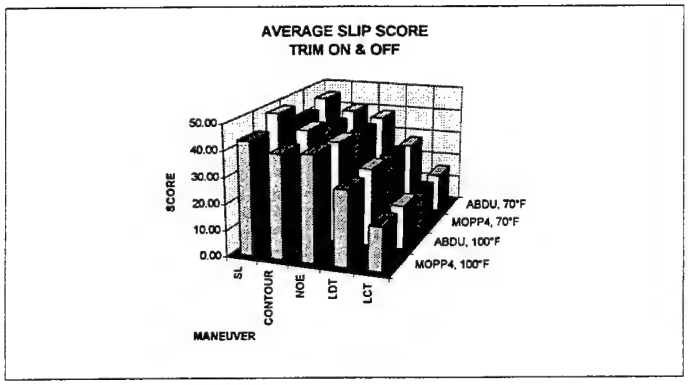
Flight performance scores: Trim on and off.

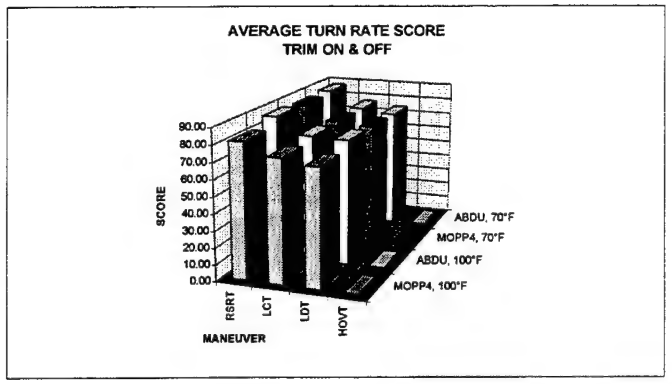


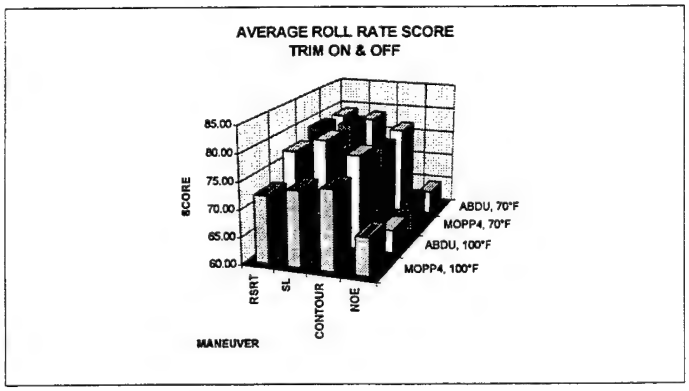












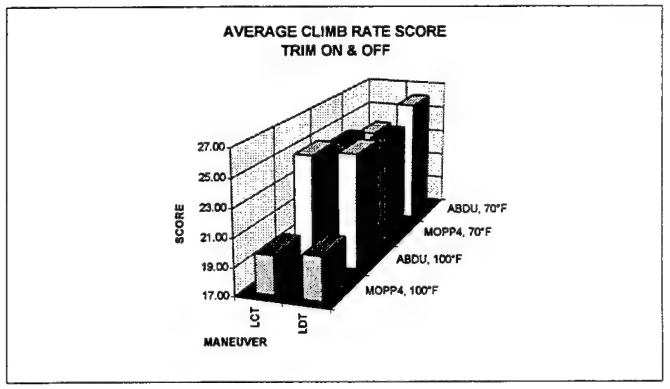
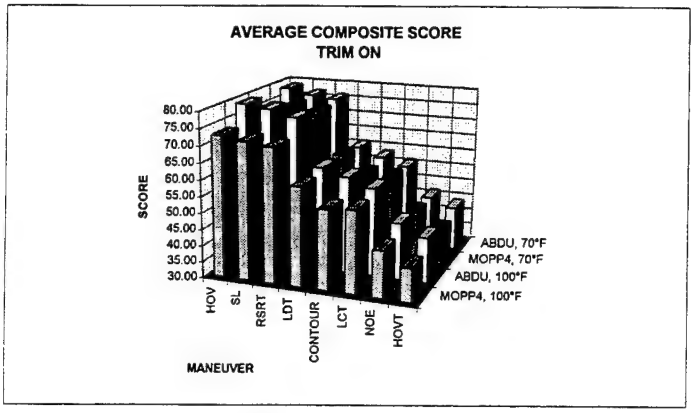
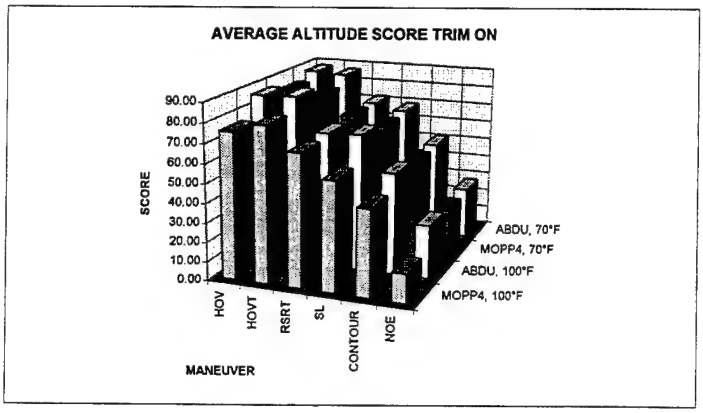
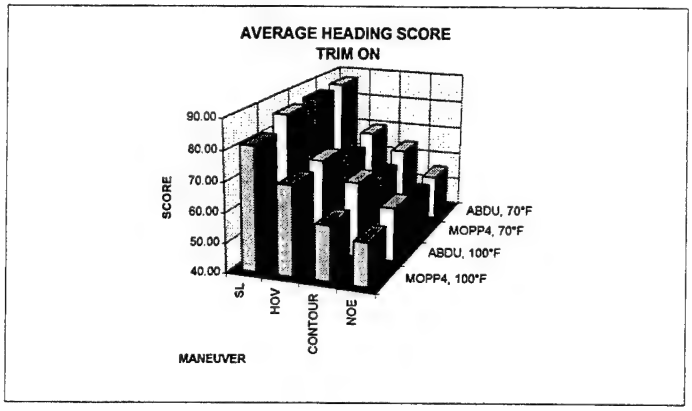


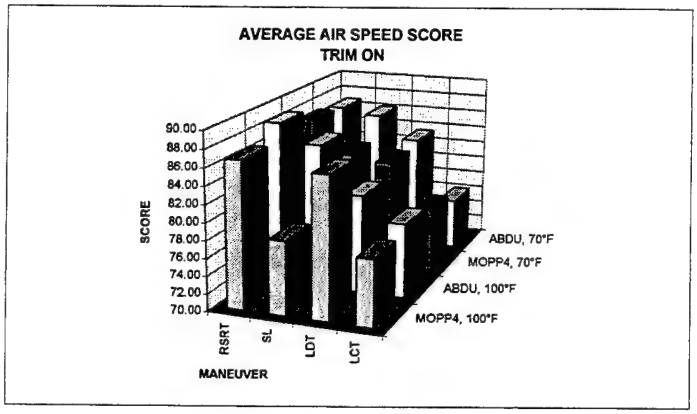
Table D-3.

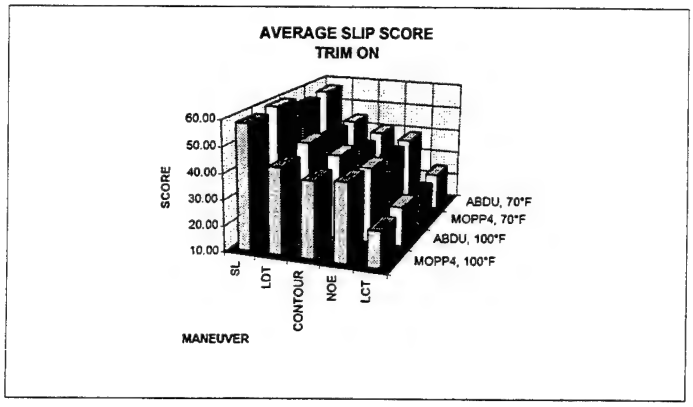
Flight performance scores: Trim on.

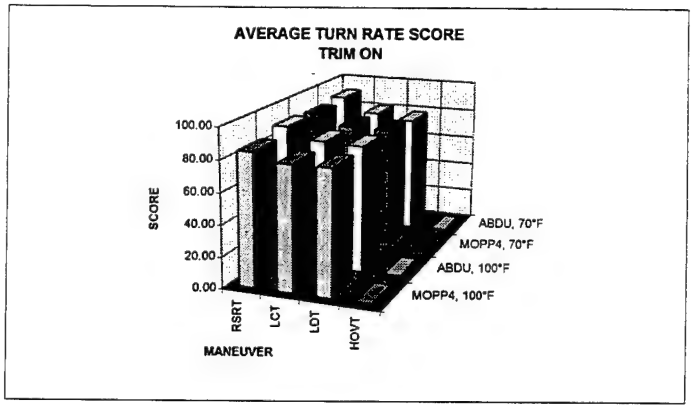


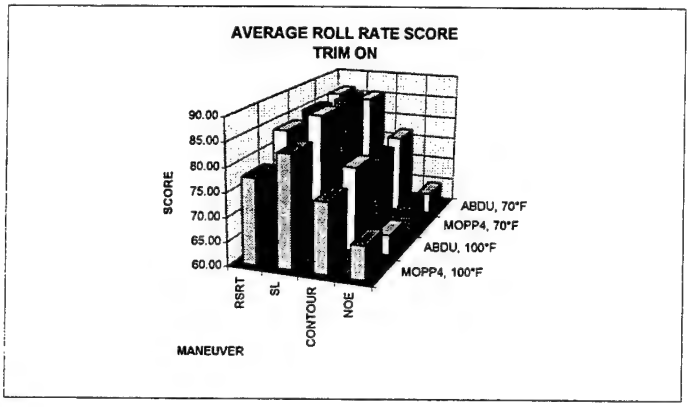












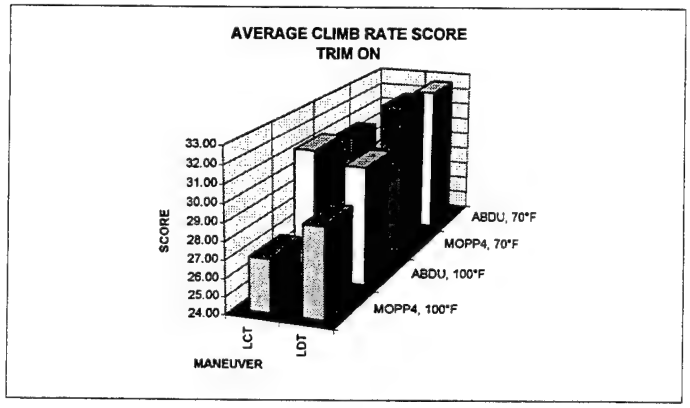
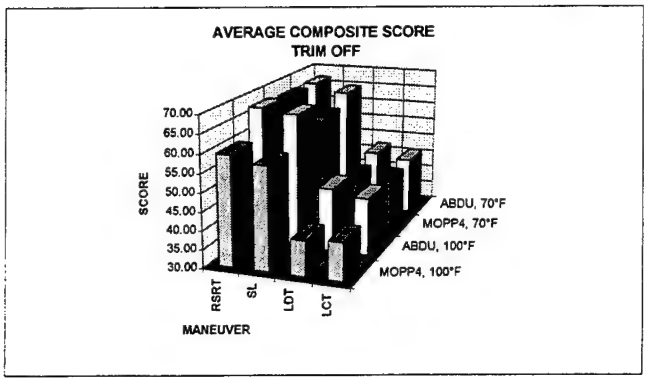
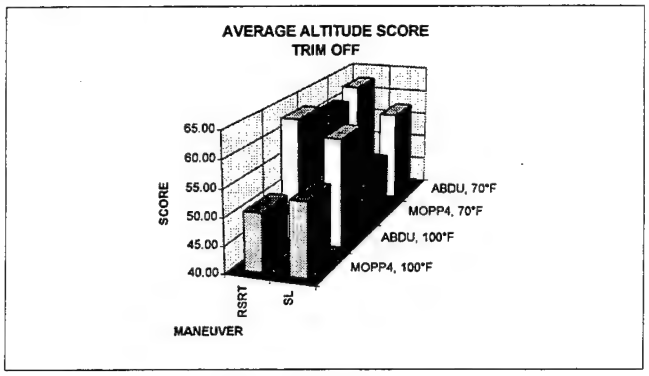
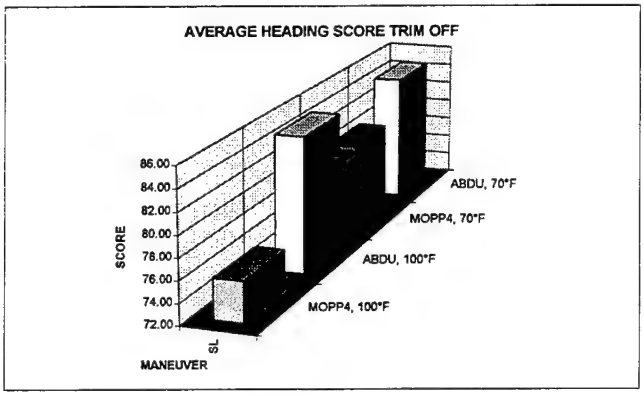


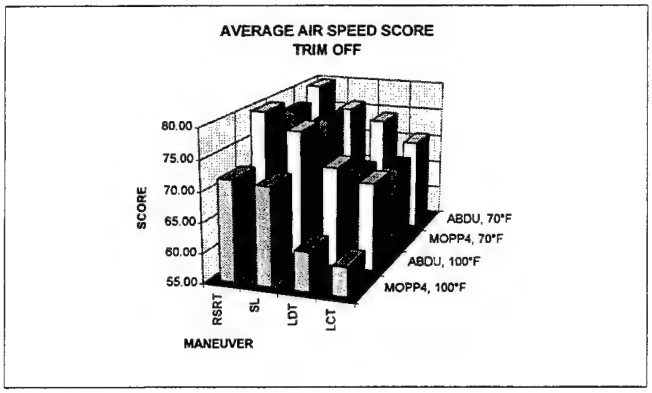
Table D-4.

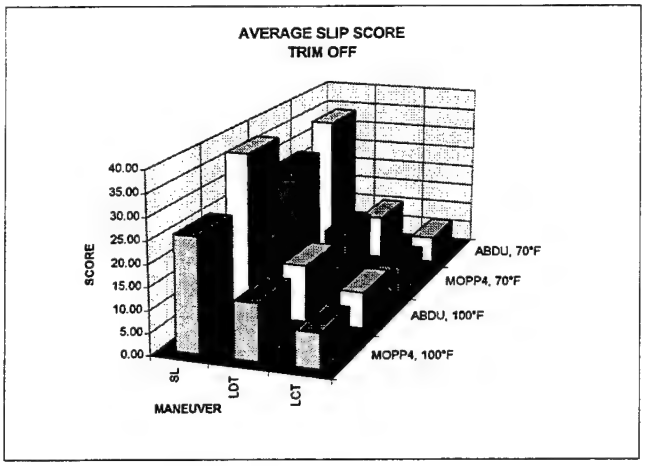
Flight performance scores: Trim off.

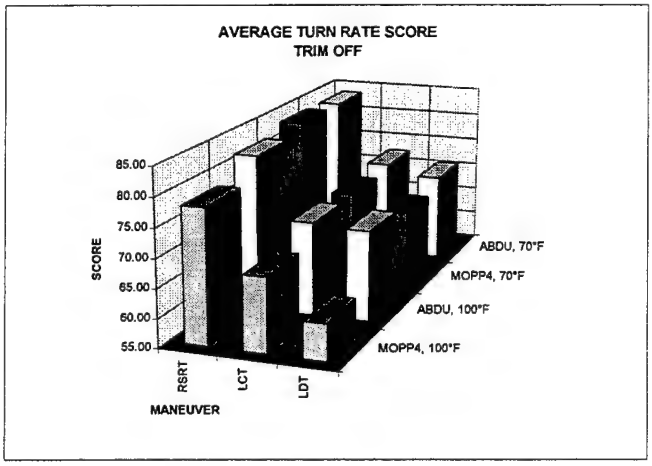


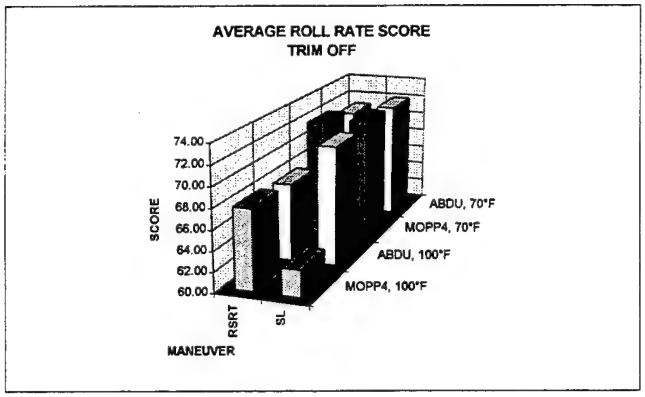












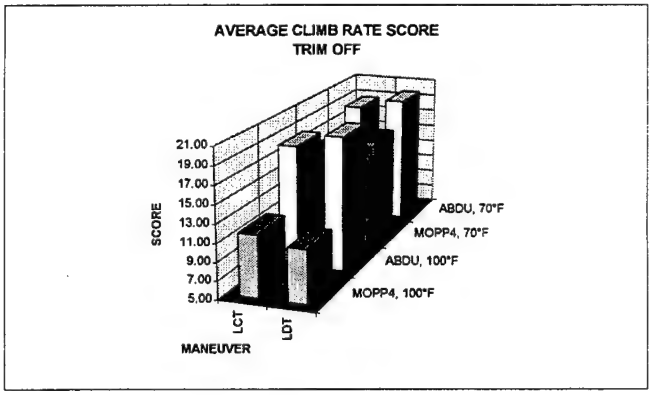
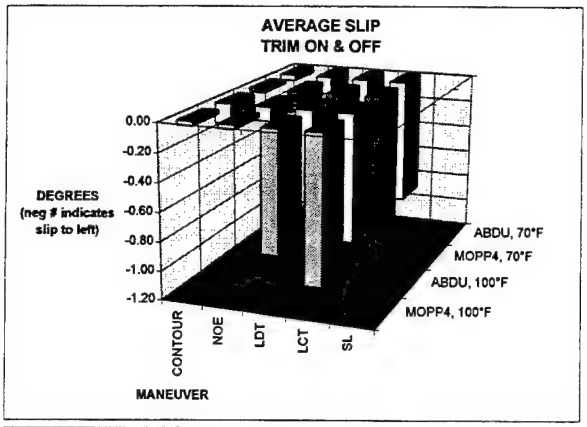
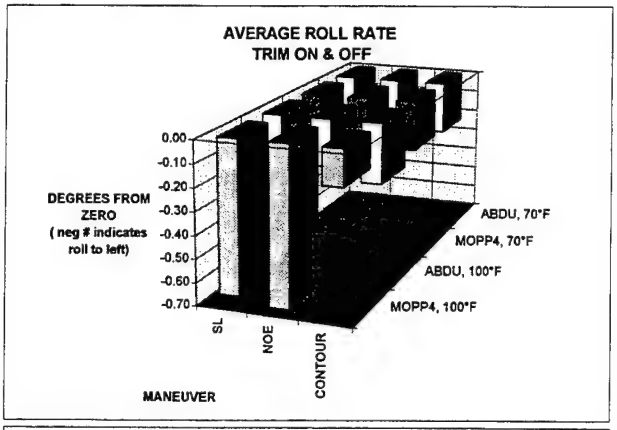
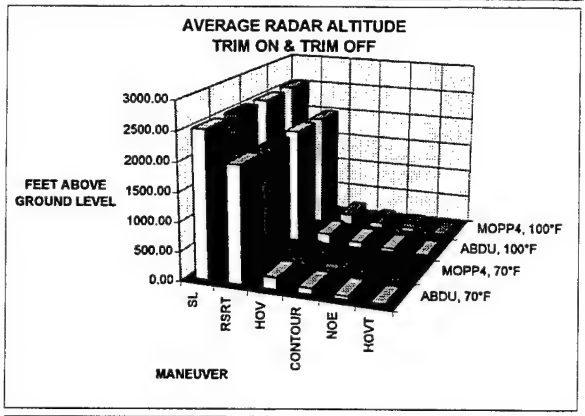


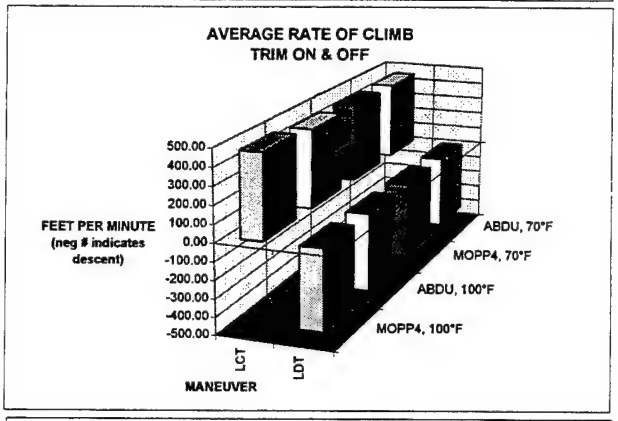
Table D-5.

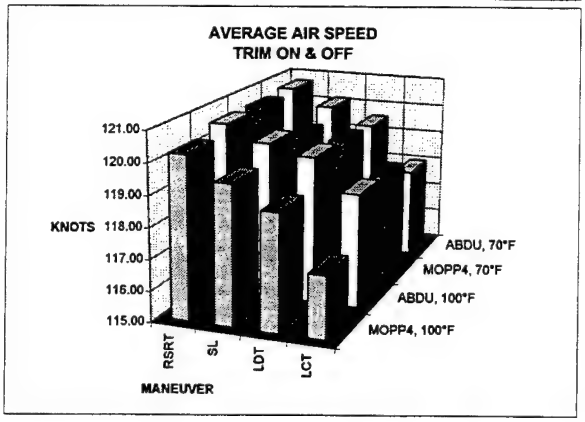
Flight performance averages by maneuver and condition: Trim on and off.











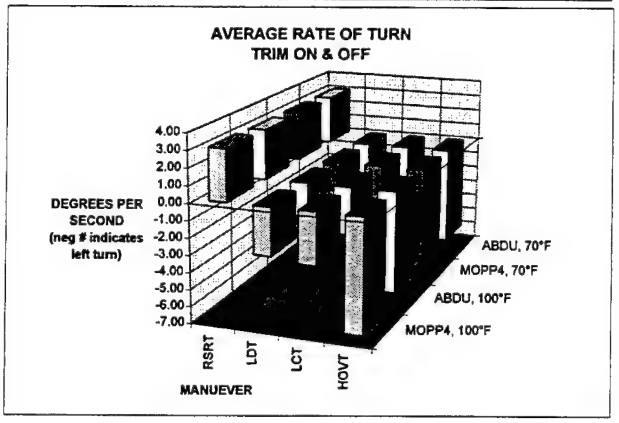
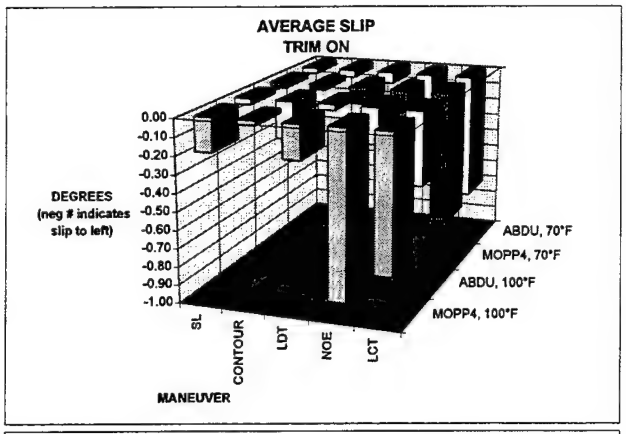
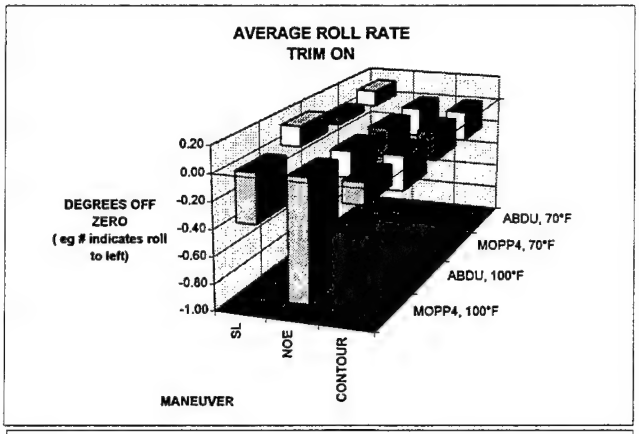
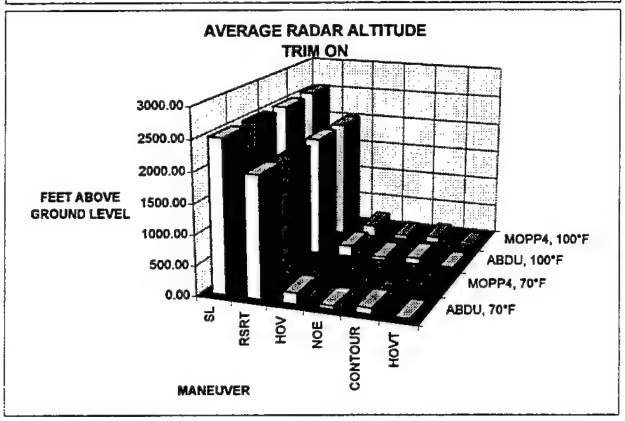


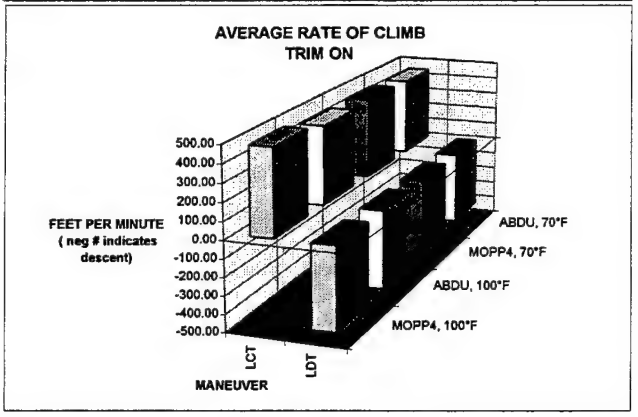
Table D-6.

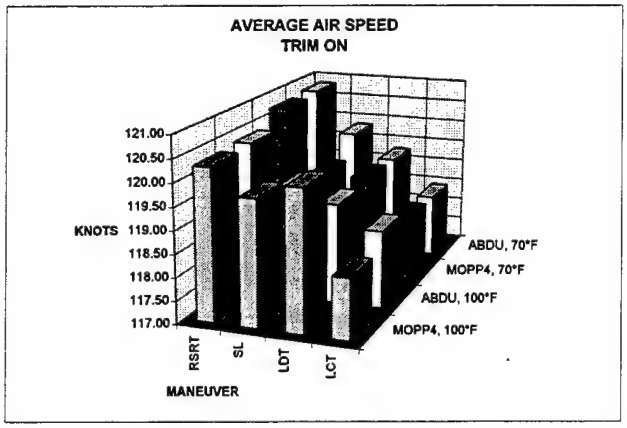
Flight parameter averages by maneuver and condition: Trim on.











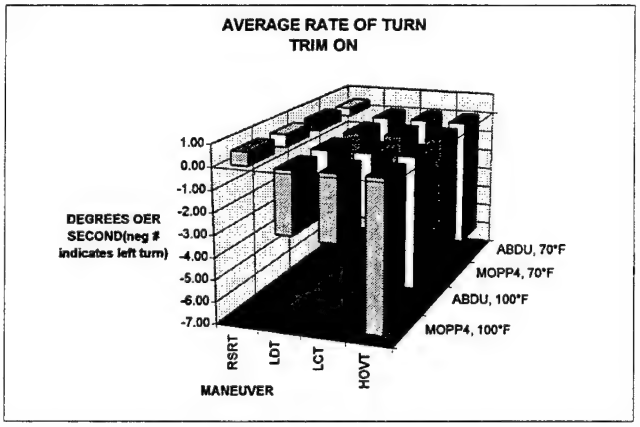
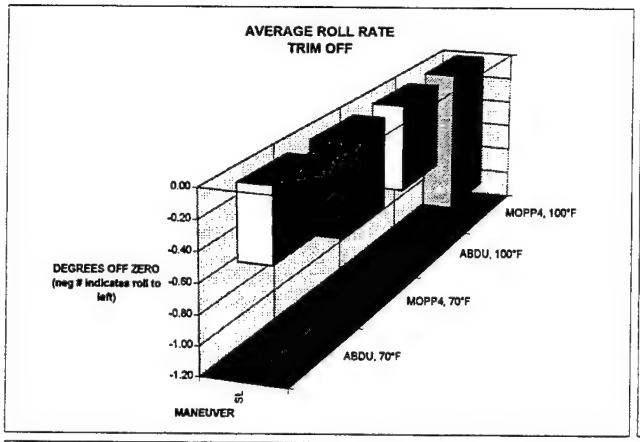
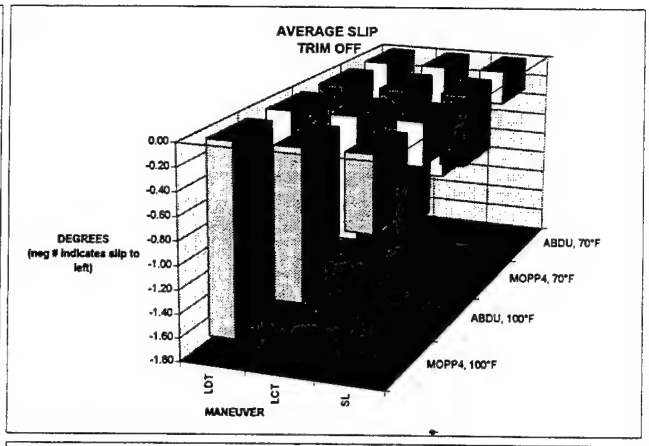
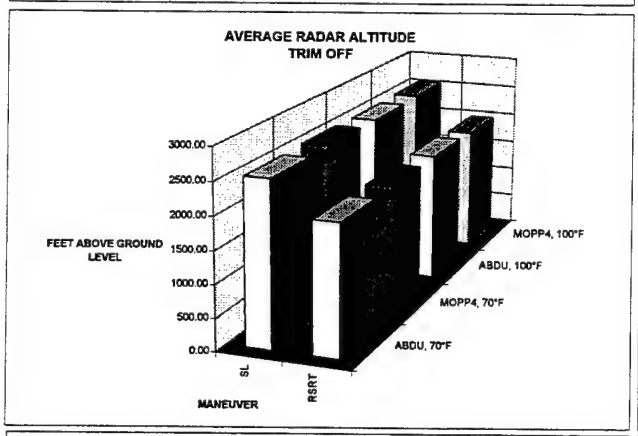


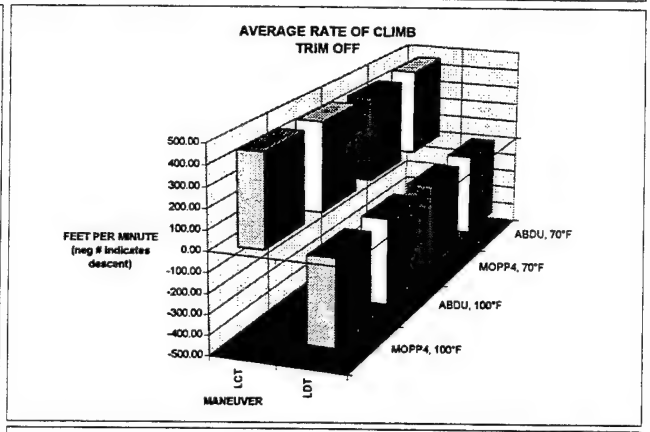
Table D-7.

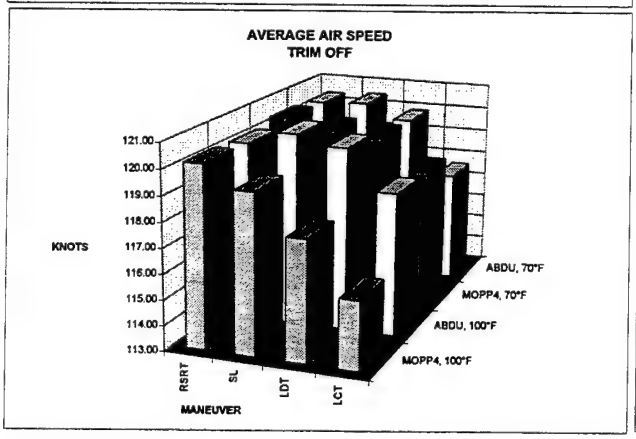
Flight parameter averages by condition: Trim off.











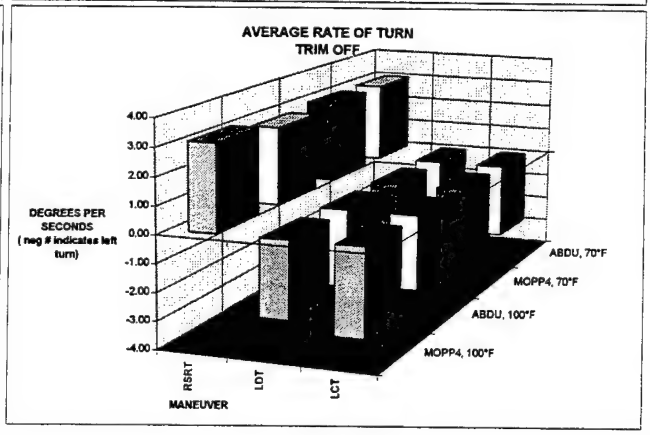
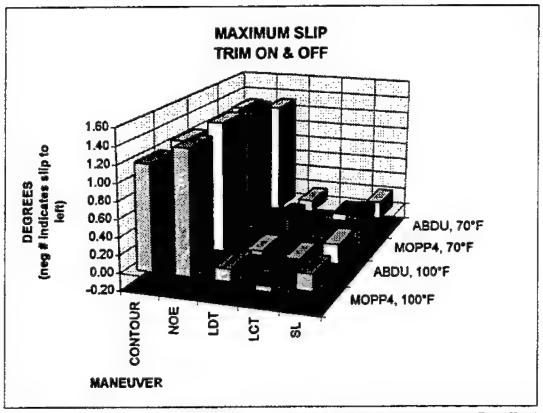
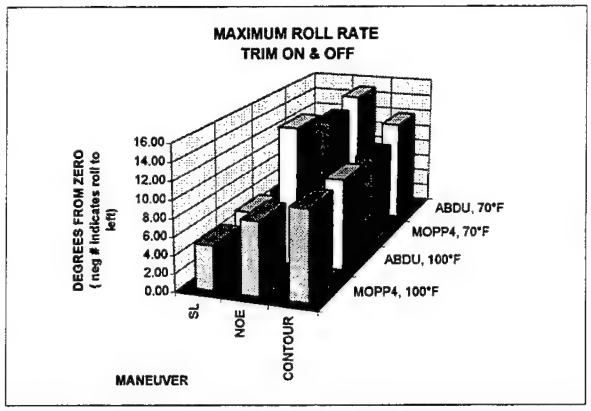
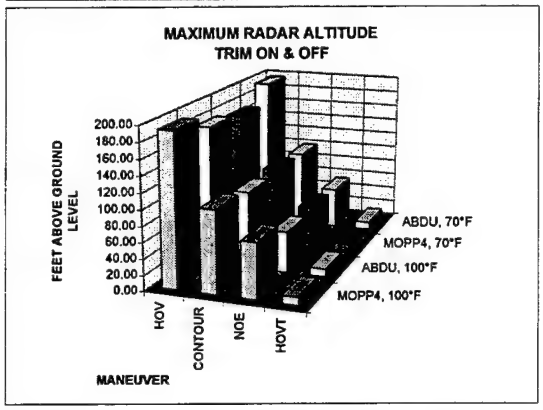


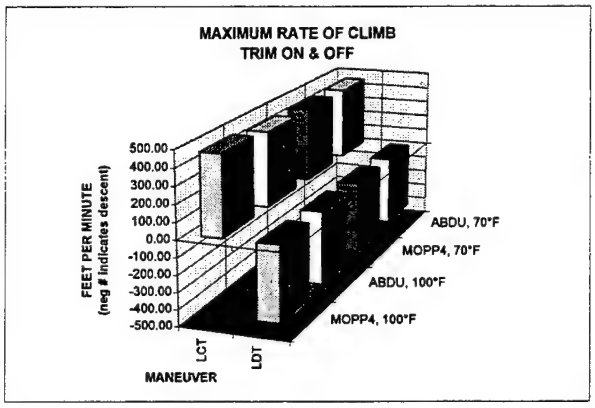
Table D-8.

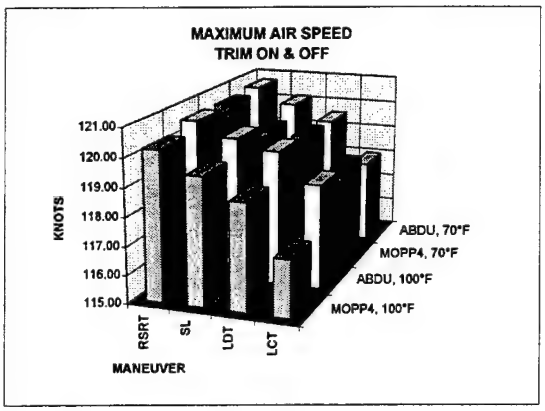
Flight parameter maximums by maneuver and condition: Trim on and off.











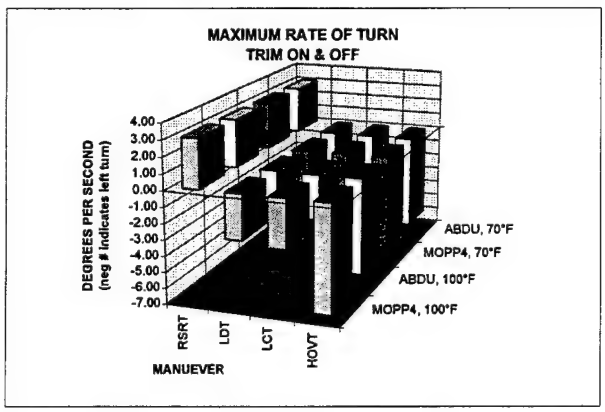
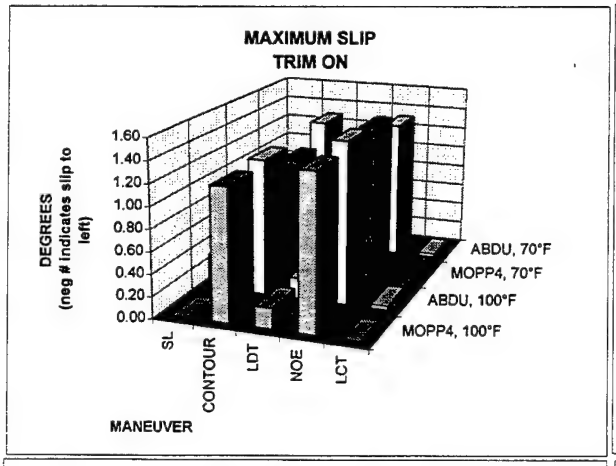
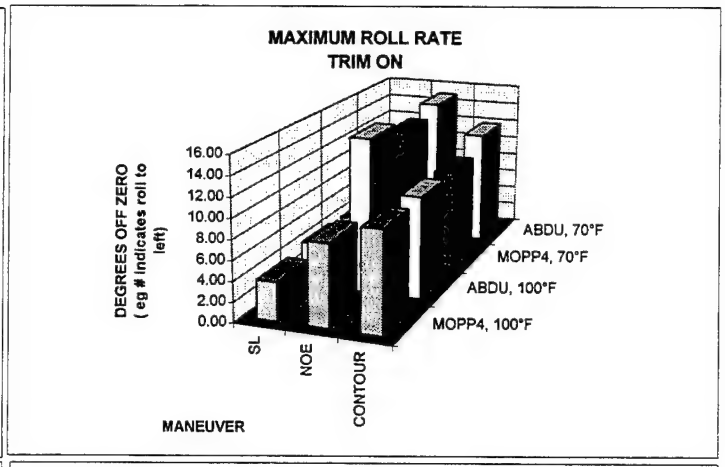
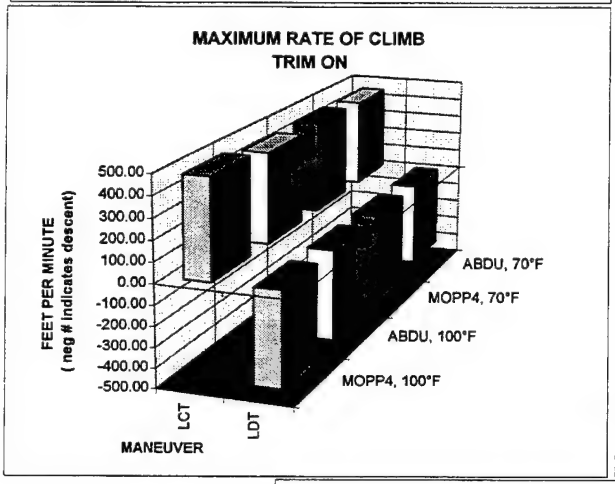


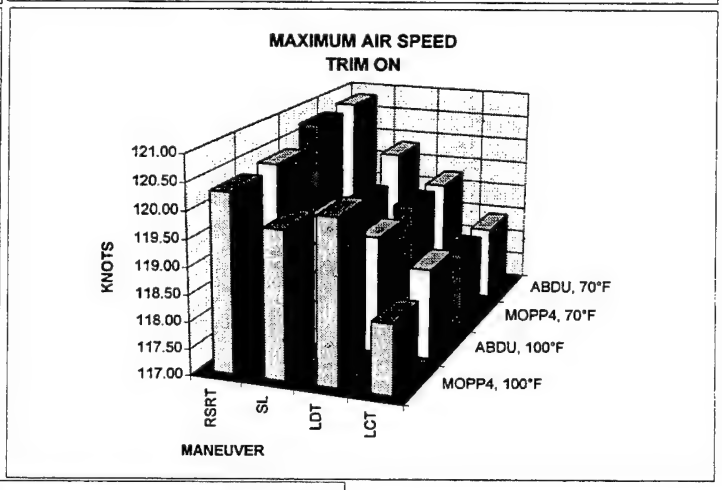
Table D-9.

Flight parameter maximums by maneuver and condition: Trim on.









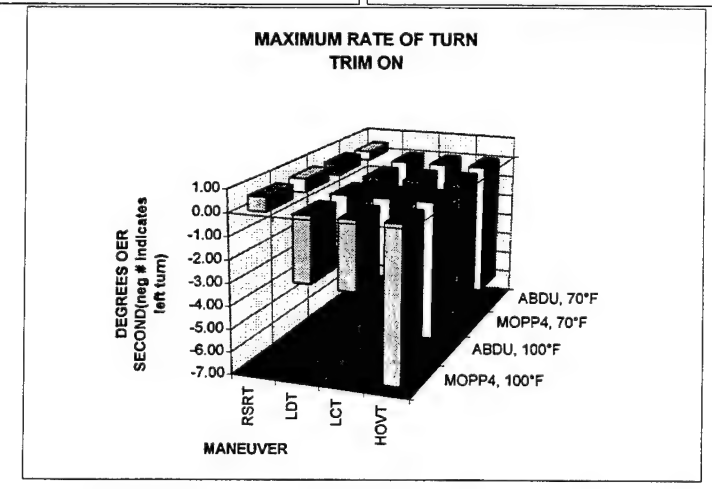
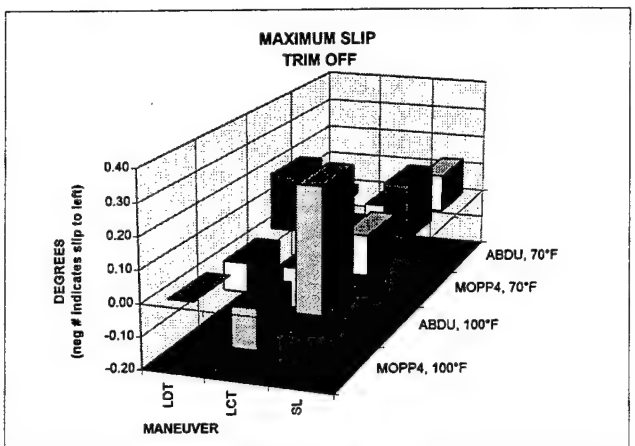
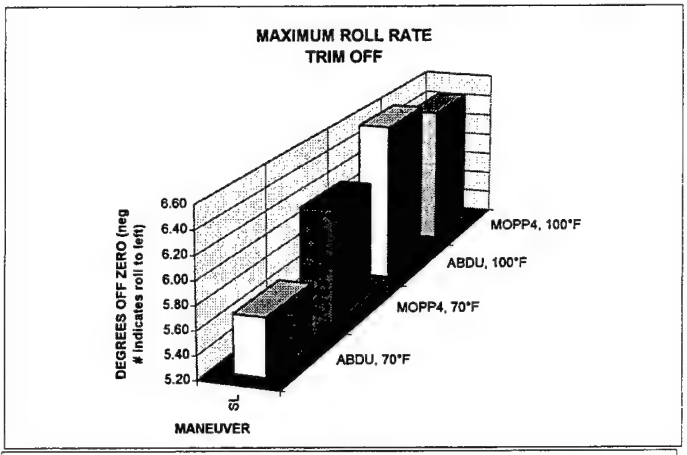
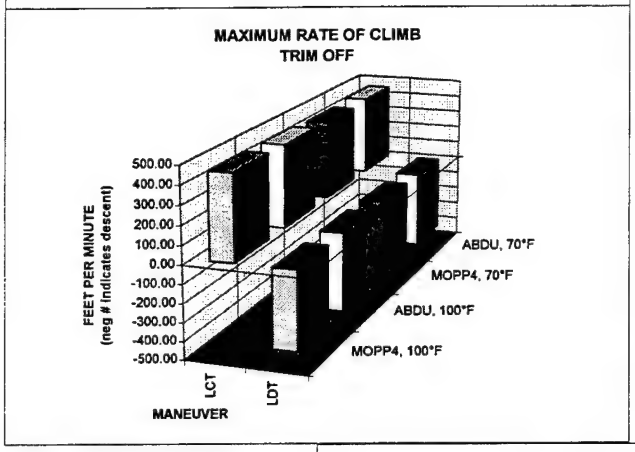


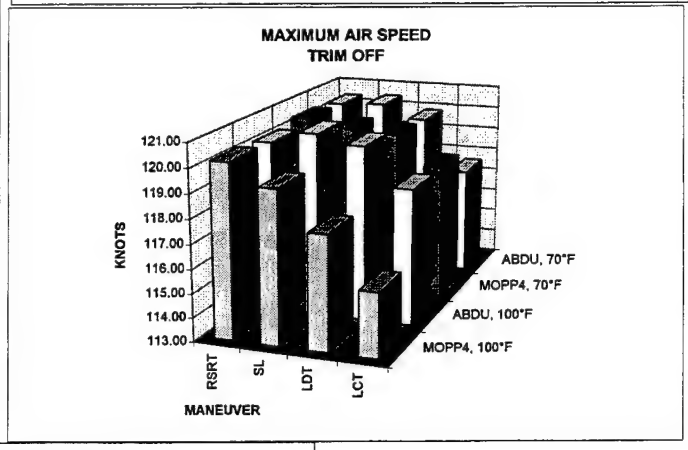
Table D-10.

Flight parameter maximums by maneuver and condition: Trim off.









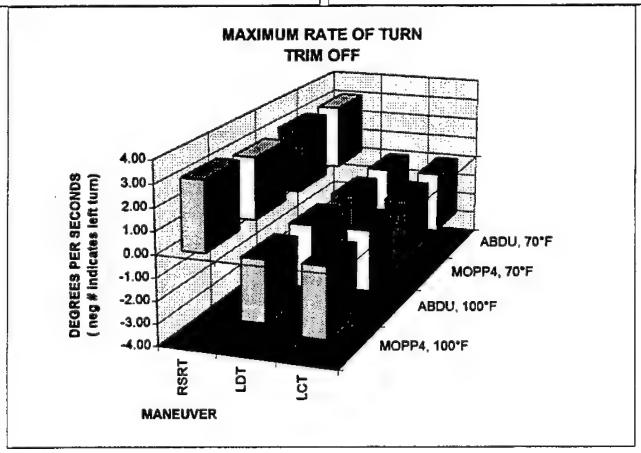
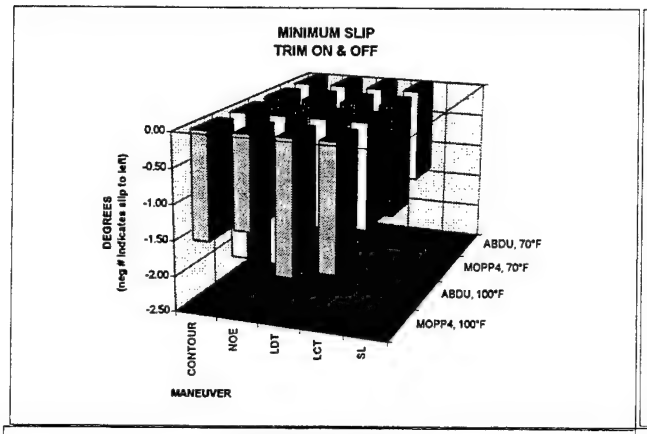
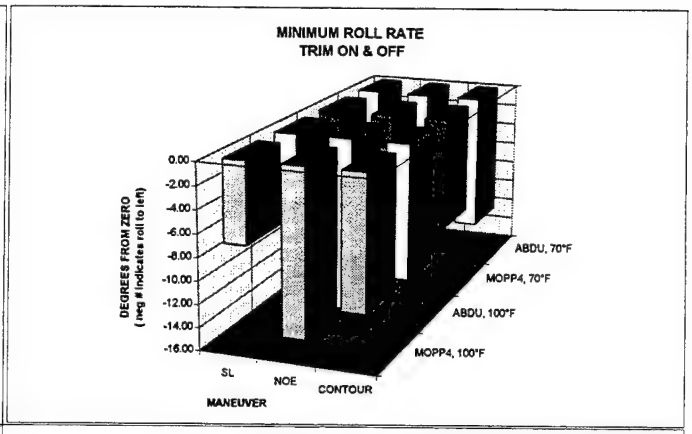
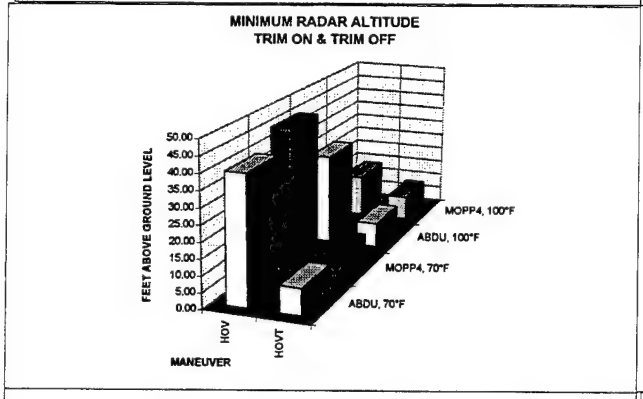


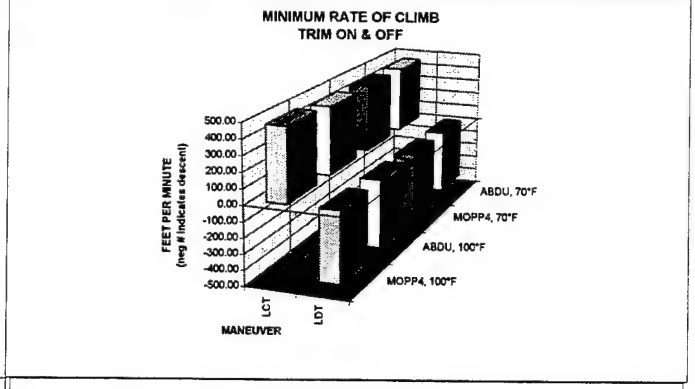
Table D-11.

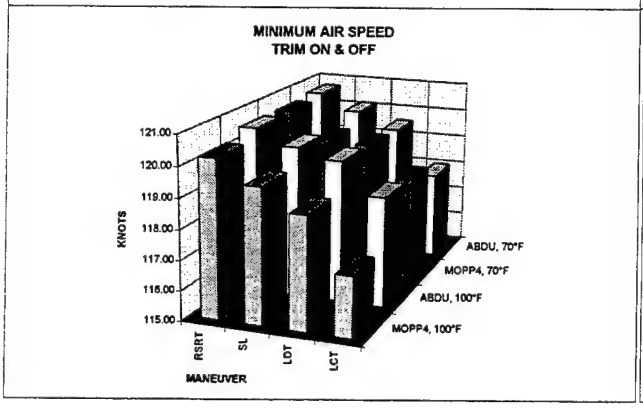
Flight parameter minimums by maneuver and condition: Trim on and off.











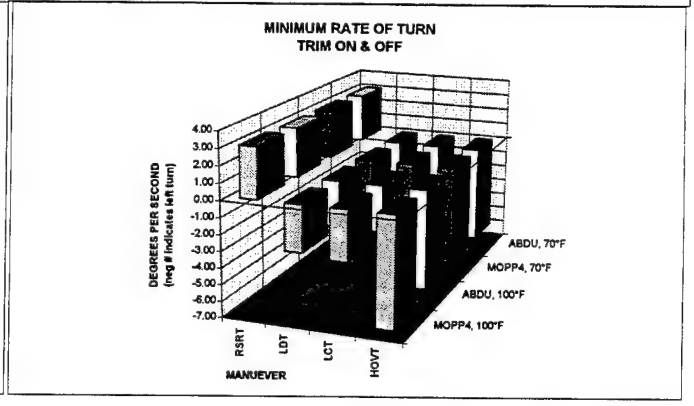


Table D-12.

Flight parameter minimums by maneuver and condition: Trim on.

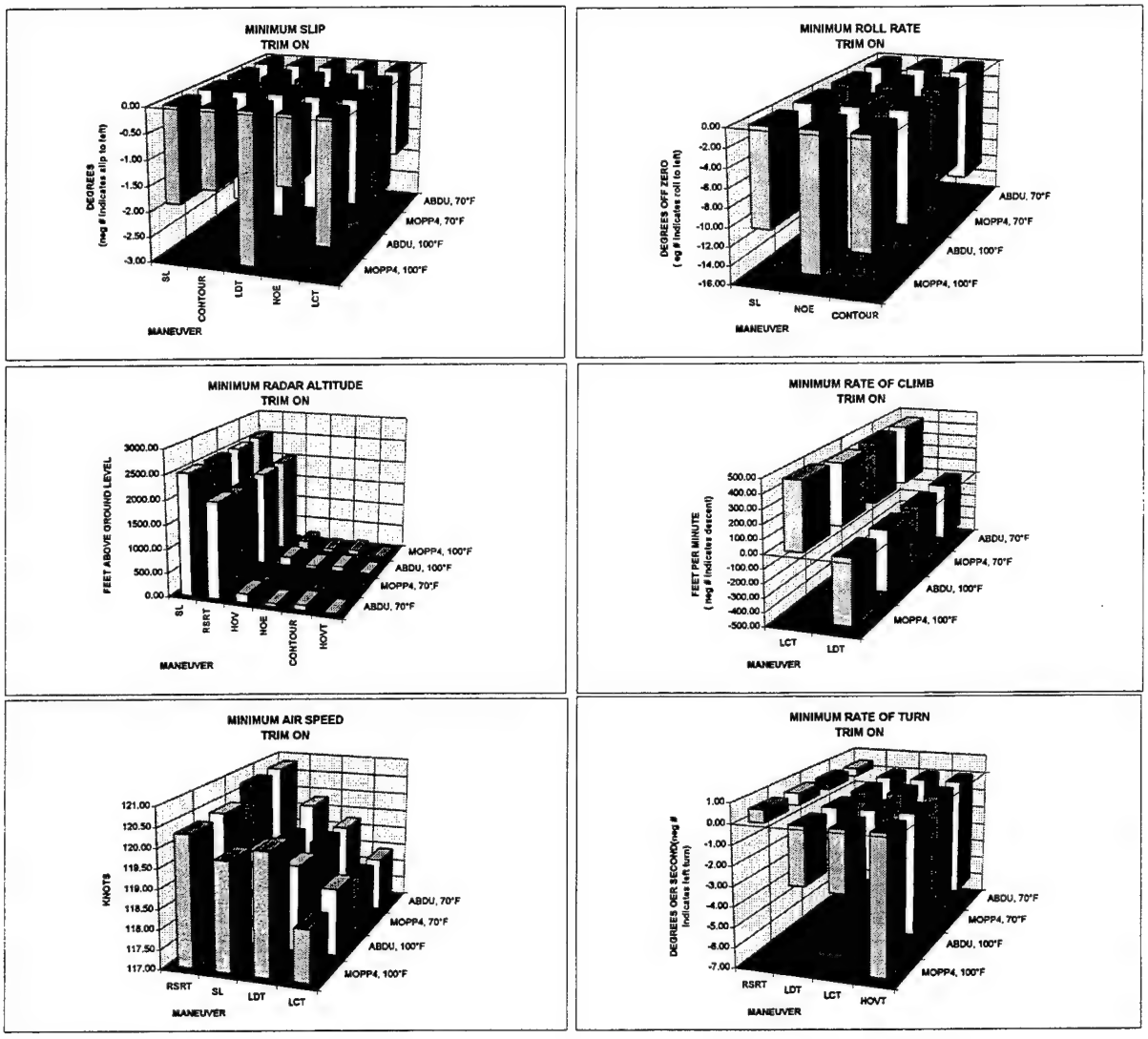
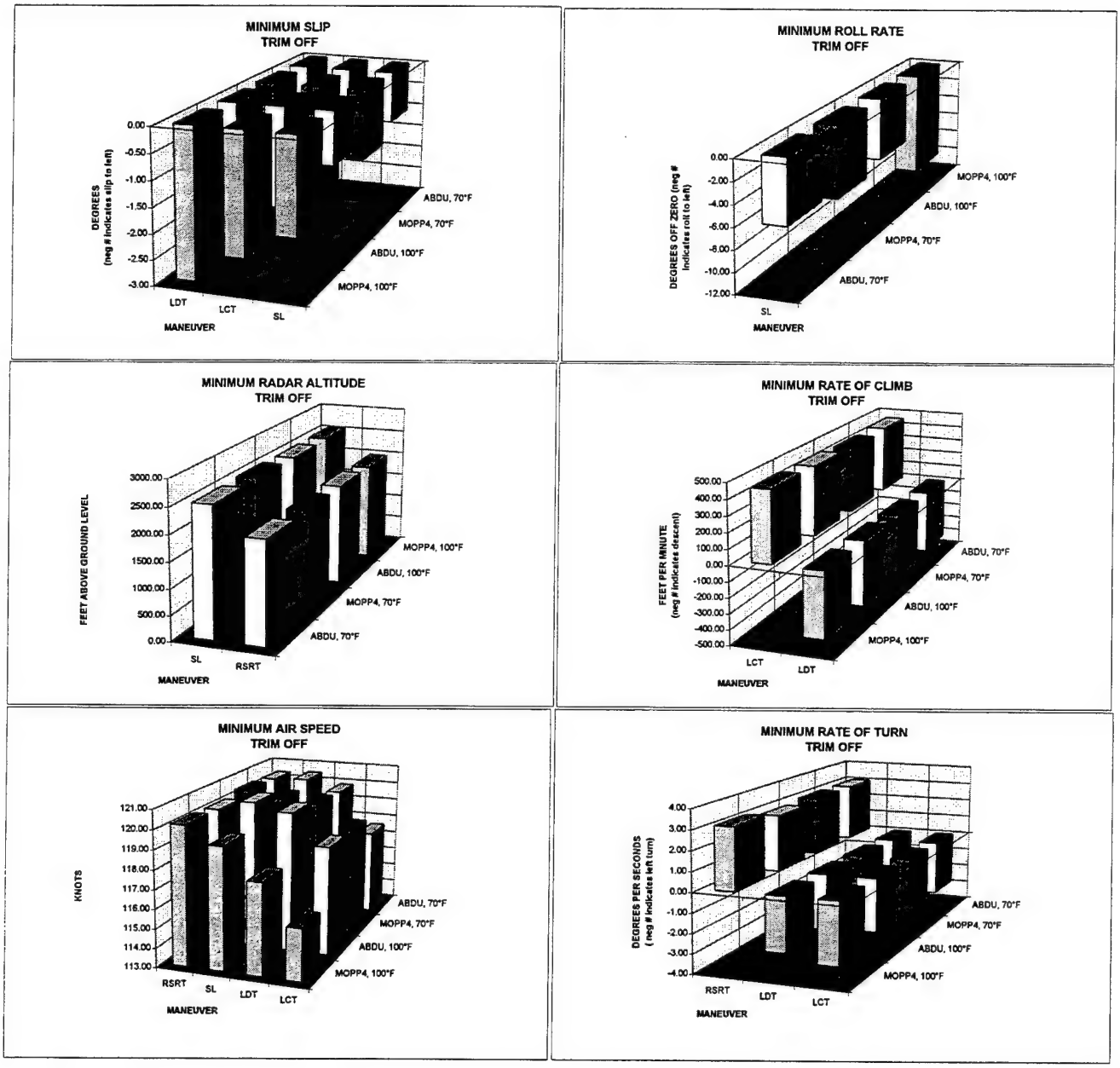


Table D-13.

Flight parameter minimums by maneuver and condition: Trim off.



Appendix E. Spectral analysis of cyclic and collective inputs.

Table E-1.

Four-way ANOVA for hover and hover turn - FFT

Hover

Summary of All Effects

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
Controls	2	1.4119	8	0.1449	9.7443	0.0072
Percent	2	9.3405	8	0.1759	53.1029	0.0000
Temperature	1	0.0015	4	0.0086	0.1706	0.7008
Uniform	1	0.0884	4	0.0134	6.6188	0.0618
Controls and Percent	4	0.9925	16	0.0916	10.8377	0.0002
Control and Temperature	2	0.0101	8	0.0085	1.1845	0.3543
Percent and Temperature	2	0.0025	8	0.0048	0.5308	0.6075
Control and Uniform	2	0.0427	8	0.0160	2.6607	0.1301
Percent and Uniform	2	0.0751	8	0.0126	5.9438	0.0262
Temperature and Uniform	1	0.0250	4	0.0255	0.9818	0.3778

Hover Turn

Summary of All Effects

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
Controls	2	2.1636	8	0.1016	21.2987	0.0006
Percent	2	11.7979	8	0.1801	65.4919	0.0000
Temperature	1	0.0141	4	0.0207	0.6791	0.4562
Uniform	1	0.0852	4	0.0316	2.6999	0.1757
Controls and Percent	4	1.4478	16	0.0519	27.8757	0.0000
Control and Temperature	2	0.0009	8	0.0150	0.0576	0.9444
Percent and Temperature	2	0.0133	8	0.0168	0.7908	0.4860
Control and Uniform	2	0.0434	8	0.0562	0.7735	0.4931
Percent and Uniform	2	0.0544	8	0.0241	2.2582	0.1669
Temperature and Uniform	1	0.0022	4	0.0494	0.0440	0.8442

Table E-2.
Repeated measures ANOVA results for FFT - Hover.

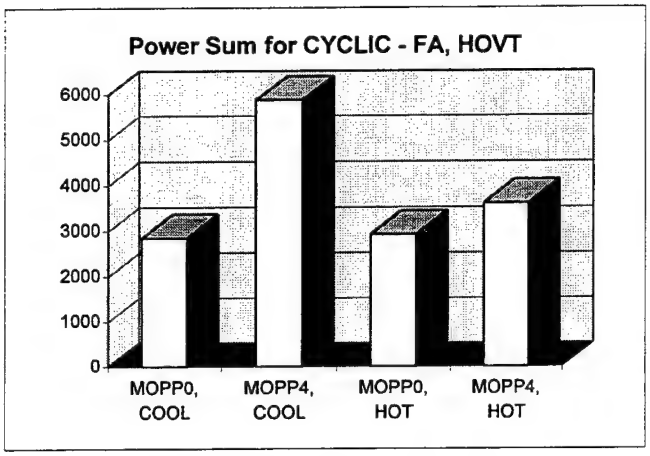
		MEAN SIMULATOR INCIDENTS BY CONDITION				MAIN EFFECTS TEMPERATURE		MAIN EFFECTS UNIFORM		INTERACTION TEMPERATURE X UNIFORM	
EVENT	NUM TSs	ABDU, 70°F	MOPP IV,70°F	ABDU, 100°F	MOPP IV, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
FA1M, 10%	6	0.04	0.04	0.03	0.05	0.11	0.7563	0.26	0.6400	3.77	0.1240
FA1M, 50%	6	0.21	0.20	0.15	0.15	2.79	0.1702	0.08	0.7864	0.01	0.9220
FA1M, 90%	6	1.03	1.13	0.92	1.14	0.87	0.4039	1.65	0.2689	0.33	0.5964
FA1M, Power Sum	6	1371.42	1676.48	1048.46	2601.30	2.09	0.2222	23.90	0.0081	5.63	0.0765
FA1M, Peak	6	0.11	0.08	0.08	0.11	0.01	0.9438	0.00	0.9874	13.05	0.0225
FA1M, Skew	6	2.61	3.44	2.72	1.81	5.13	0.0861	0.01	0.9217	15.01	0.0179
FA1M, Frequecy Band	6	0.99	1.10	0.88	1.09	1.07	0.3598	1.52	0.2851	0.23	0.6583
FB1M, 10%	6	0.02	0.02	0.02	0.02	1.34	0.3108	0.03	0.8805	8.58	0.0428
FB1M, 50%	6	0.10	0.13	0.09	0.14	0.03	0.8609	5.45	0.0798	0.61	0.4799
FB1M, 90%	6	0.84	0.96	0.76	1.12	0.63	0.4718	11.44	0.0277	0.98	0.3784
FA1B,Power Sum	6	2703.44	3641.57	1935.30	5580.44	1.71	0.2606	234.19	0.0001	4.67	0.0967
FA1B, Peak	6	0.05	0.04	0.04	0.04	4.67	0.0967	1.37	0.3060	2.49	0.1894
FA1B, Skew	6	2.10	2.50	2.28	2.86	0.41	0.5562	3.39	0.1394	0.19	0.6858
FA1B, Frequency Band	6	0.81	0.94	0.74	1.10	0.82	0.4173	11.33	0.0281	0.95	0.3839
FCOLL, 10%	6	0.03	0.02	0.03	0.03	0.16	0.7129	0.07	0.8017	2.68	0.1769
FCOLL, 50%	6	0.09	0.06	0.07	0.07	0.45	0.5379	4.20	0.1097	1.25	0.3262
FCOLL, 90%	6	0.29	0.26	0.31	0.29	0.30	0.6147	0.30	0.6116	0.00	0.9581
FCOLL, Power Sum	6	39637.00	41443.73	16867.98	163092.73	3.80	0.1229	4.84	0.0926	5.67	0.0758
FCOLL, Peak	6	0.06	0.05	0.05	0.07	3.37	0.1404	1.61	0.2732	4.87	0.0919
FCOLL, Skew	6	2.19	1.65	1.64	0.94	37.44	0.0036	6.12	0.0686	0.16	0.7059
FCOLL, Frequency Band	6	0.26	0.24	0.29	0.26	0.30	0.6149	0.28	0.6252	0.01	0.9298

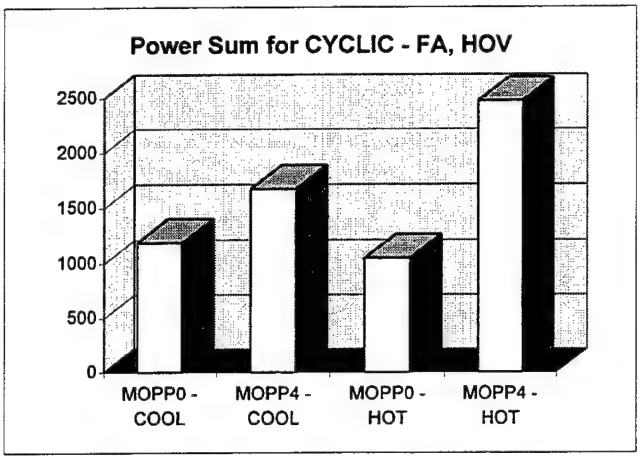
Table E-3.
Repeated measures ANOVA results for FFT - Hover turn.

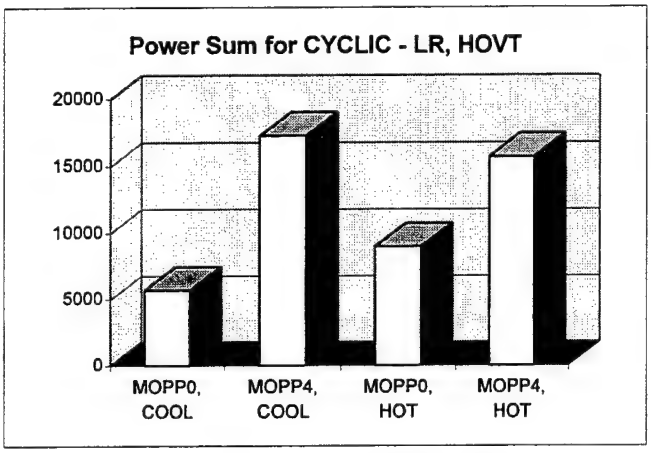
		MEAN SIMULATOR INCIDENTS BY CONDITION				MAIN EFFECTS				INTERACTION	
						TEMPERATURE		UNIFORM		TEMPERATURE X UNIFORM	
EVENT	NUM TSs	ABDU, 70°F	MOPP IV,70°F	ABDU, 100°F	MOPP IV, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
FA1M, 10%	6	0.04	0.04	0.03	0.03	5.11	0.0867	0.12	0.7440	0.43	0.5476
FA1M, 50%	6	0.21	0.21	0.18	0.19	1.84	0.2466	0.06	0.8178	0.01	0.9373
FA1M, 90%	6	1.14	1.24	1.06	1.45	0.76	0.4315	3.41	0.1386	1.29	0.3187
FA1M, Power Sum	6	3273.44	5883.71	2921.73	3871.74	0.61	0.4789	1.91	0.2386	0.99	0.3761
FA1M, Peak	6	0.09	0.10	0.07	0.04	2.11	0.2201	0.06	0.8127	0.64	0.4671
FA1M, Skew	6	2.79	3.27	2.94	3.68	0.40	0.5628	1.93	0.2375	0.07	0.8092
FA1M, Frequecy Band	6	1.10	1.20	1.03	1.42	1.08	0.3578	3.41	0.1383	1.50	0.2873
FB1M, 10%	6	0.02	0.03	0.03	0.02	0.36	0.5824	0.04	0.8491	1.18	0.3389
FB1M, 50%	6	0.16	0.21	0.17	0.22	0.07	0.7979	0.79	0.4241	0.00	0.9531
FB1M, 90%	6	0.94	1.10	1.00	1.14	0.16	0.7058	0.69	0.4523	0.01	0.9459
FA1B,Power Sum	6	6483.82	17269.20	8959.81	24907.22	0.48	0.5277	1.79	0.2520	0.06	0.8117
FA1B, Peak	6	0.06	0.06	0.05	0.06	0.16	0.7065	0.24	0.6529	0.05	0.8303
FA1B, Skew	6	2.93	3.44	3.82	3.31	0.68	0.4570	0.00	0.9988	6.64	0.0615
FA1B, Frequency Band	6	0.92	1.07	0.98	1.12	0.18	0.6939	0.73	0.4416	0.00	0.9631
FCOLL, 10%	6	0.02	0.02	0.03	0.03	1.07	0.3591	0.05	0.8379	0.00	0.9517
FCOLL, 50%	6	0.05	0.07	0.08	0.08	2.19	0.2127	0.13	0.7343	0.30	0.6113
FCOLL, 90%	6	0.27	0.26	0.36	0.25	1.16	0.3421	0.76	0.4333	0.69	0.4535
FCOLL, Power Sum	6	2992462.75	4249567.50	1604444.75	287602.06	1.61	0.2738	0.00	0.9811	0.42	0.5524
FCOLL, Peak	6	0.03	0.05	0.06	0.05	0.73	0.4400	0.01	0.9445	0.38	0.5723
FCOLL, Skew	6	1.79	2.08	2.07	2.52	0.15	0.7159	0.22	0.6605	0.01	0.9236
FCOLL, Frequency Band	6	0.24	0.24	0.33	0.22	0.67	0.4580	0.88	0.4025	0.66	0.4620

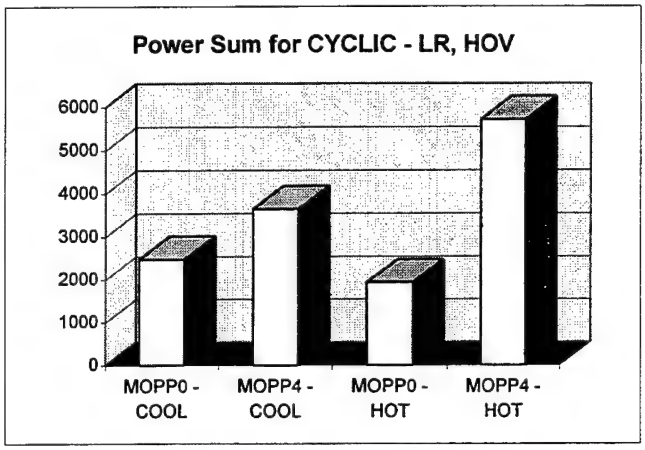
Table E-4.

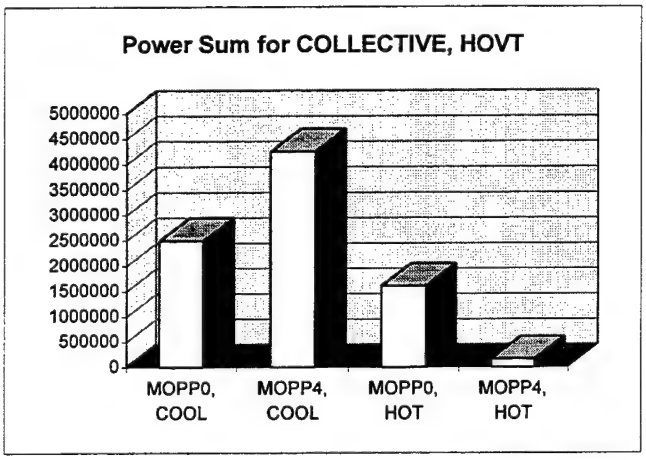
Spectral analysis results - Power sum.











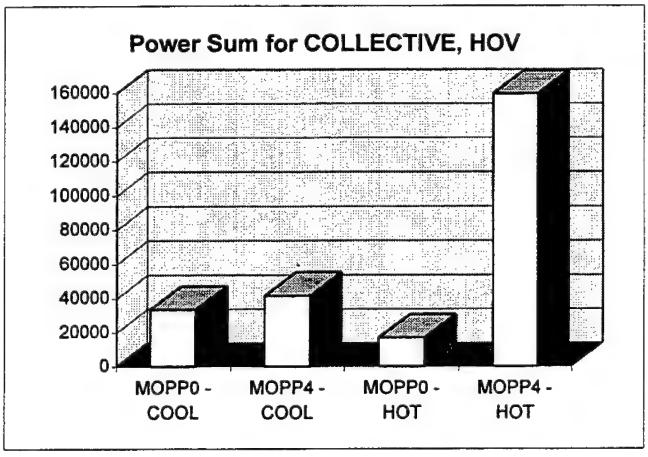
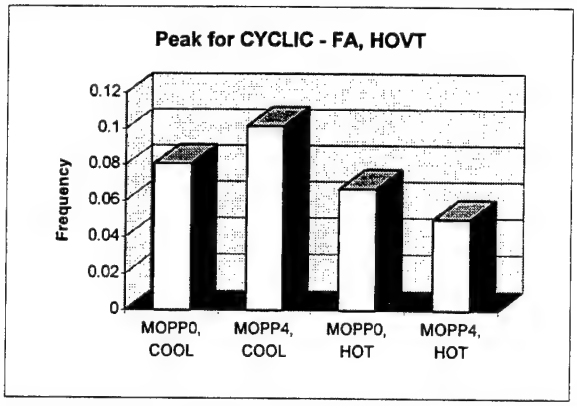
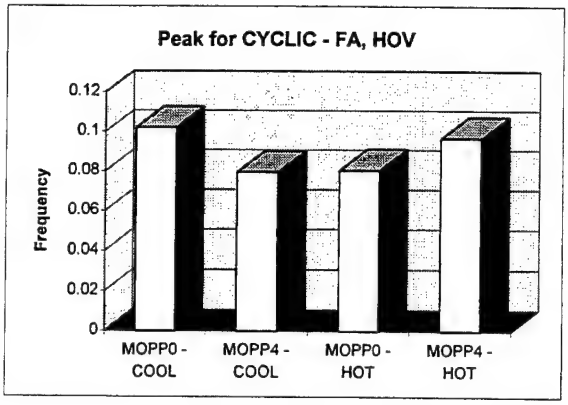
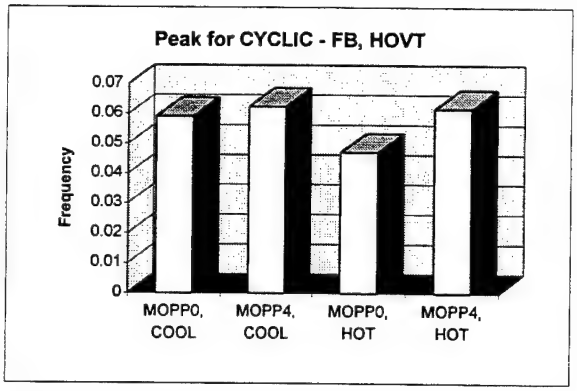


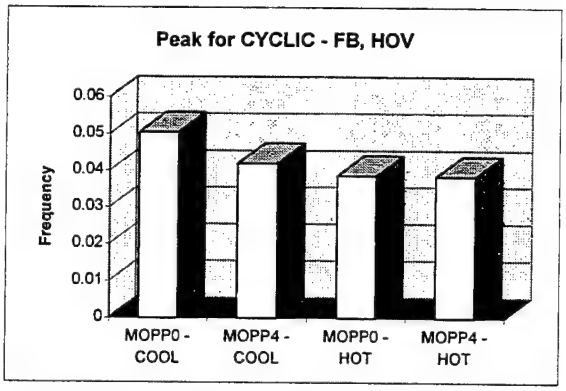
Table E-5.

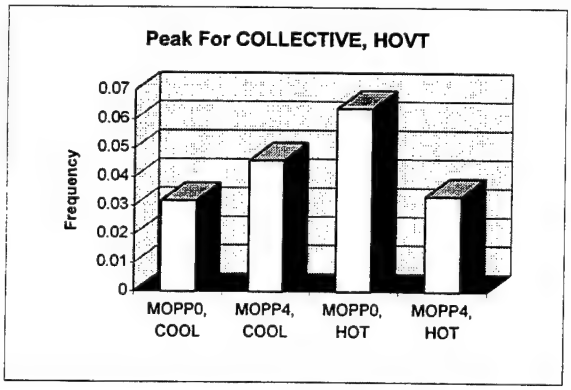
Spectral analysis results - Peak.











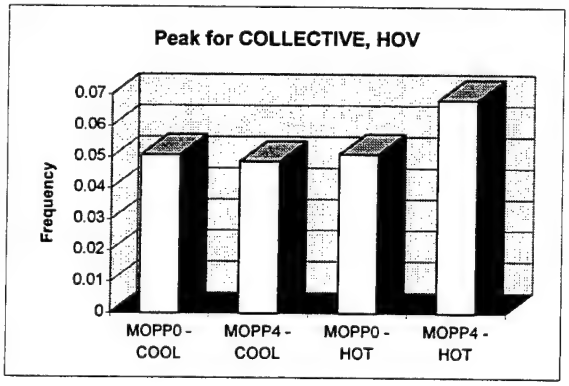
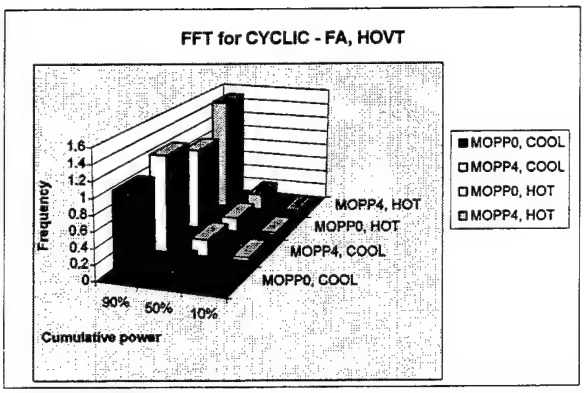
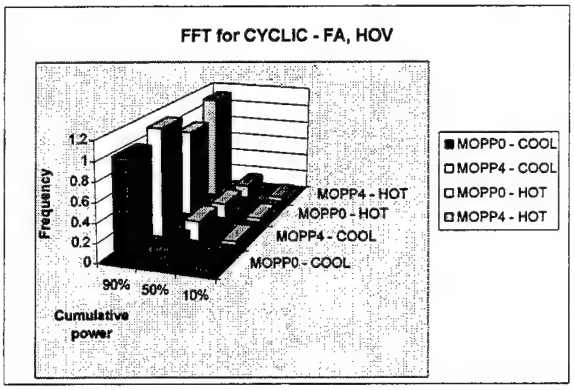
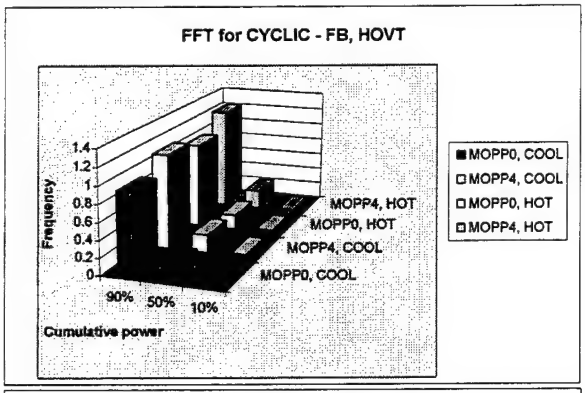


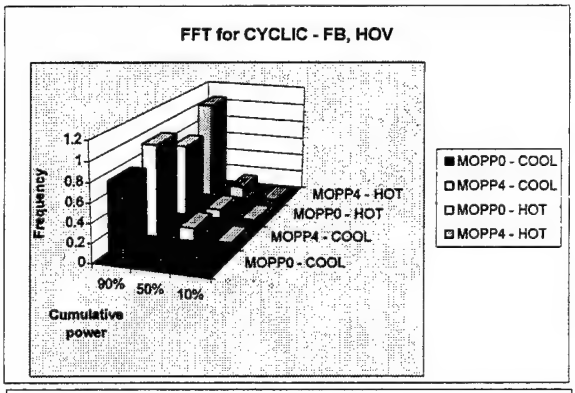
Table E-6.

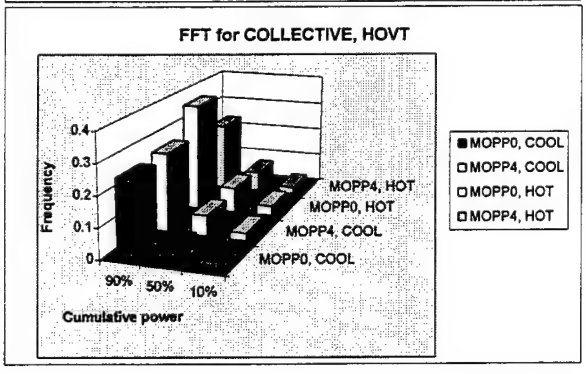
Spectral analysis results - Cumulative power.











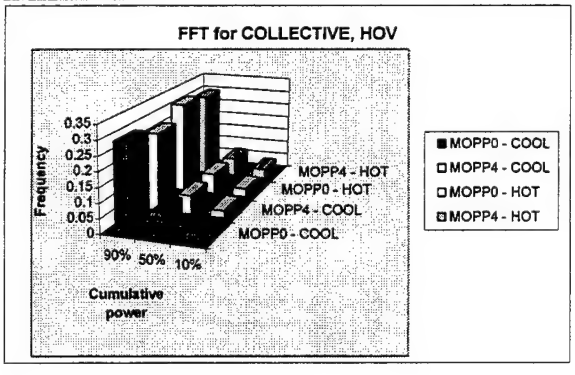
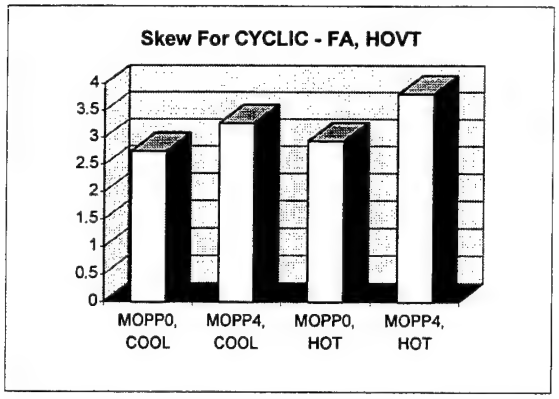
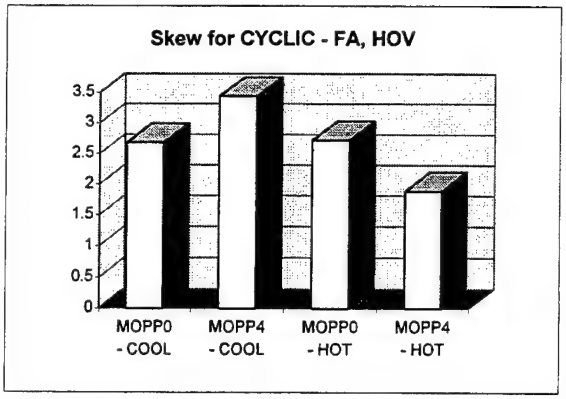
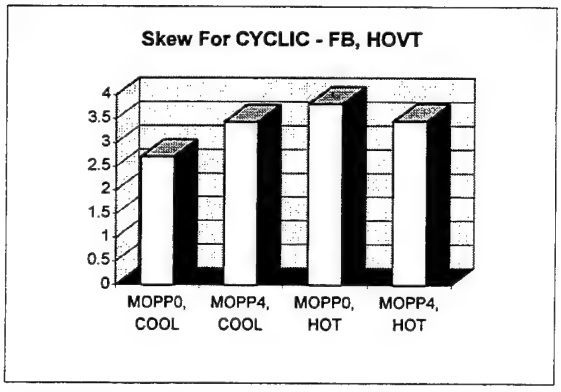
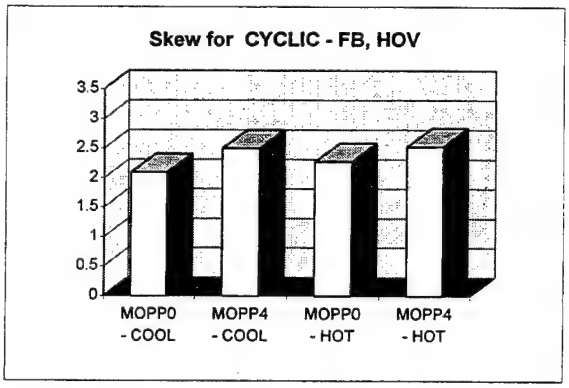


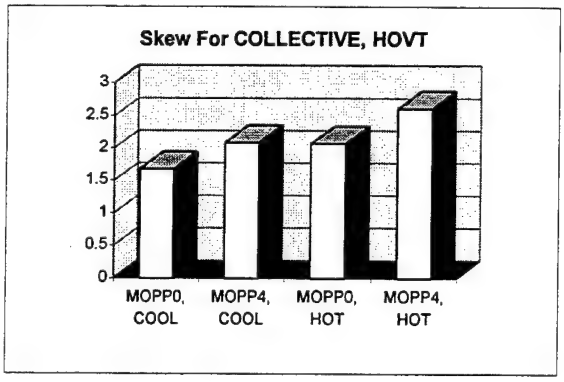
Table E-7.
Spectral analysis results - Skew.











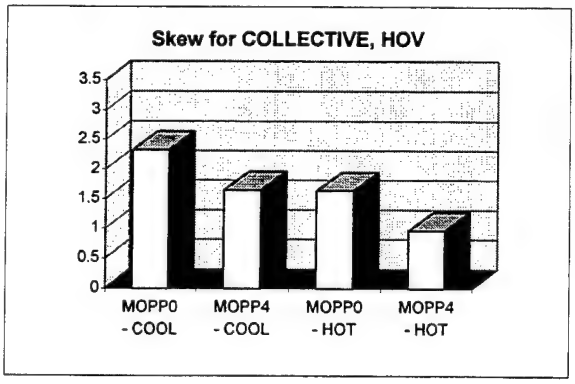
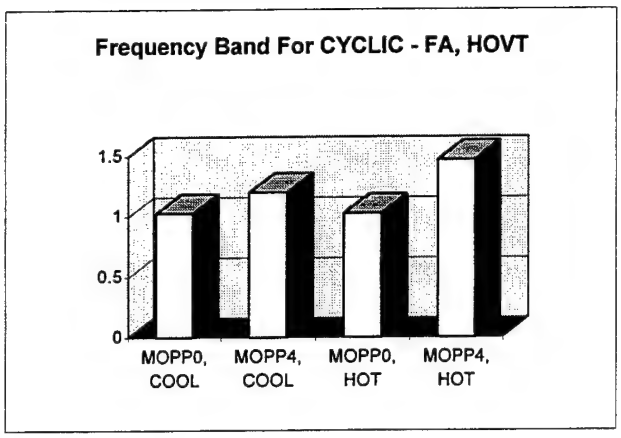
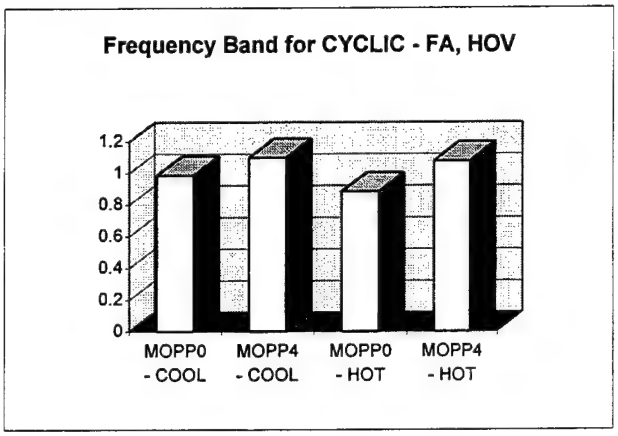
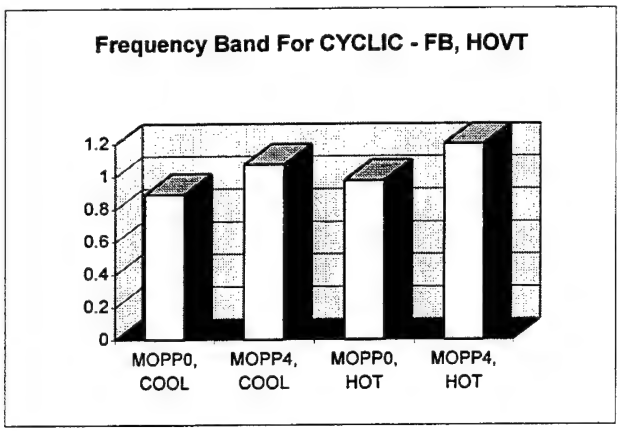


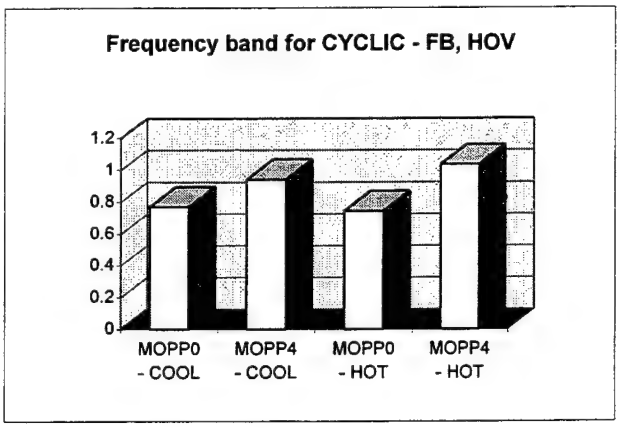
Table E-8.

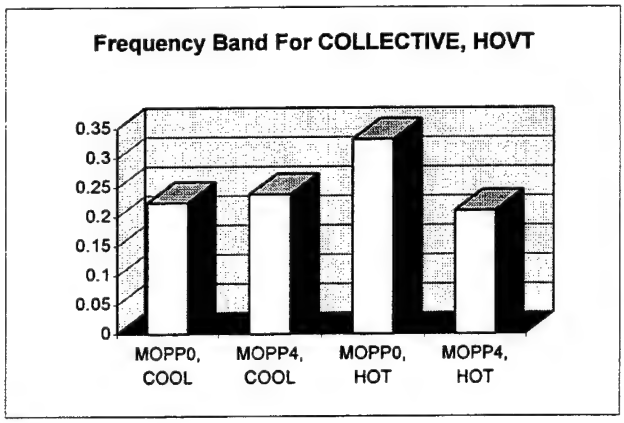
Spectral analysis results - Frequency band.

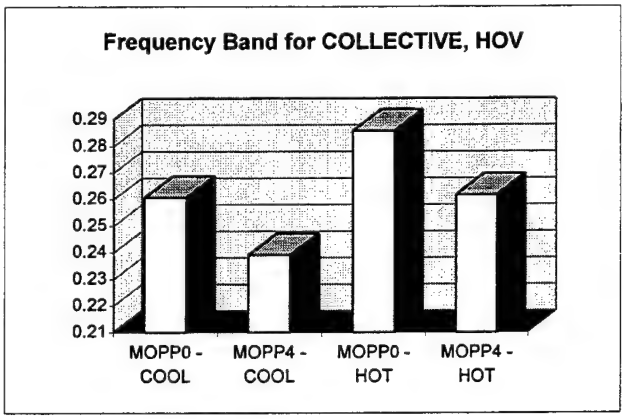








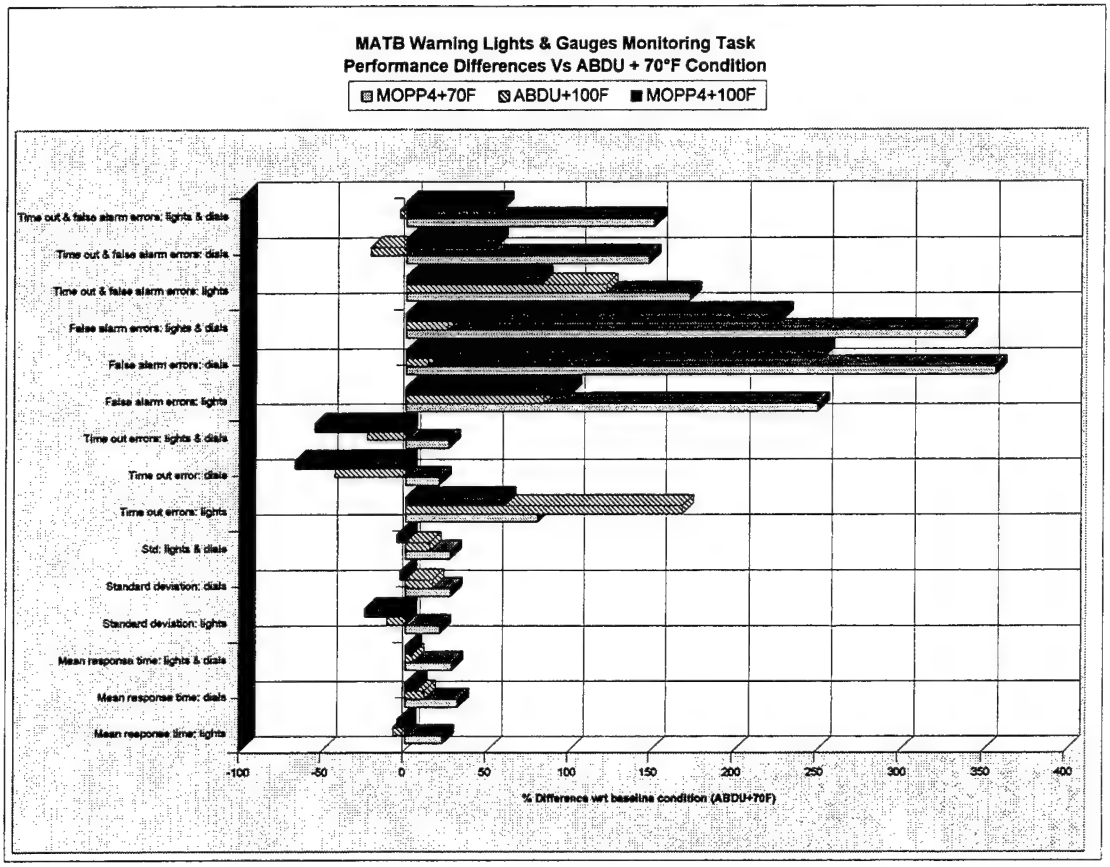




Appendix F. MATB performance and scripts.

Table F-2.

MATB: Performance on the tracking and fuel management tasks.



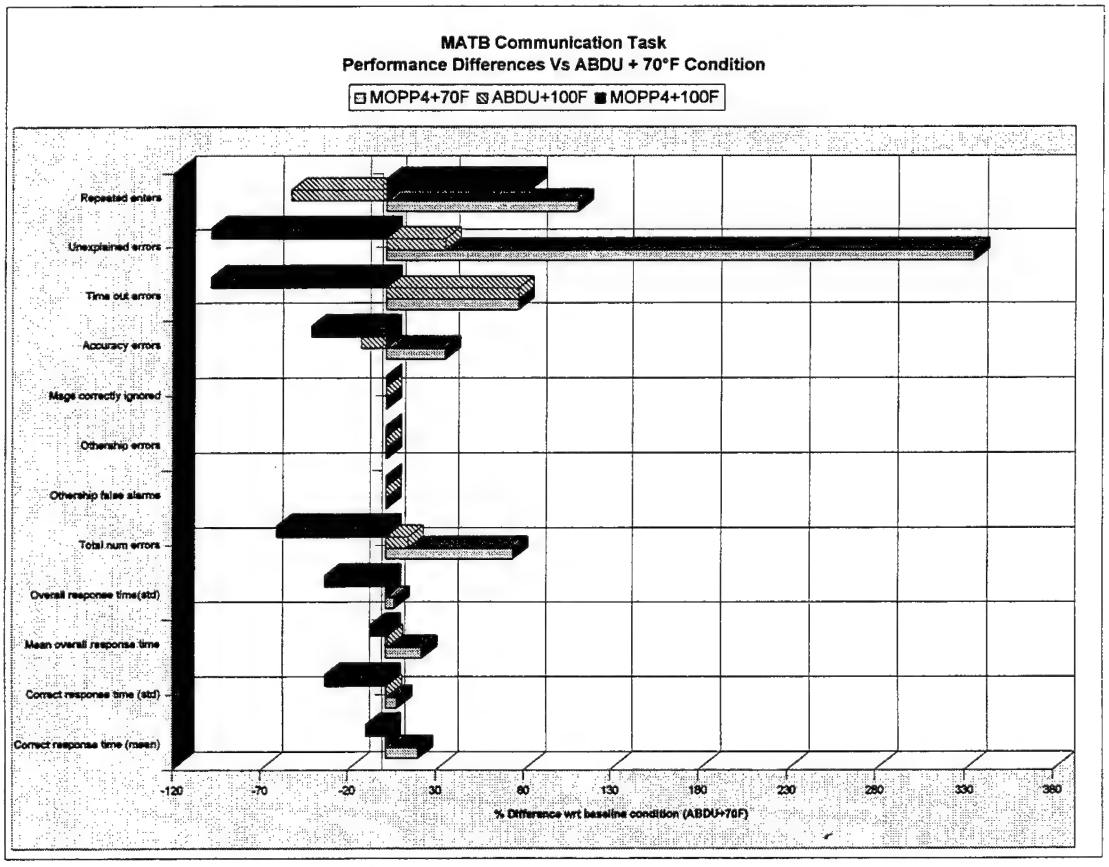
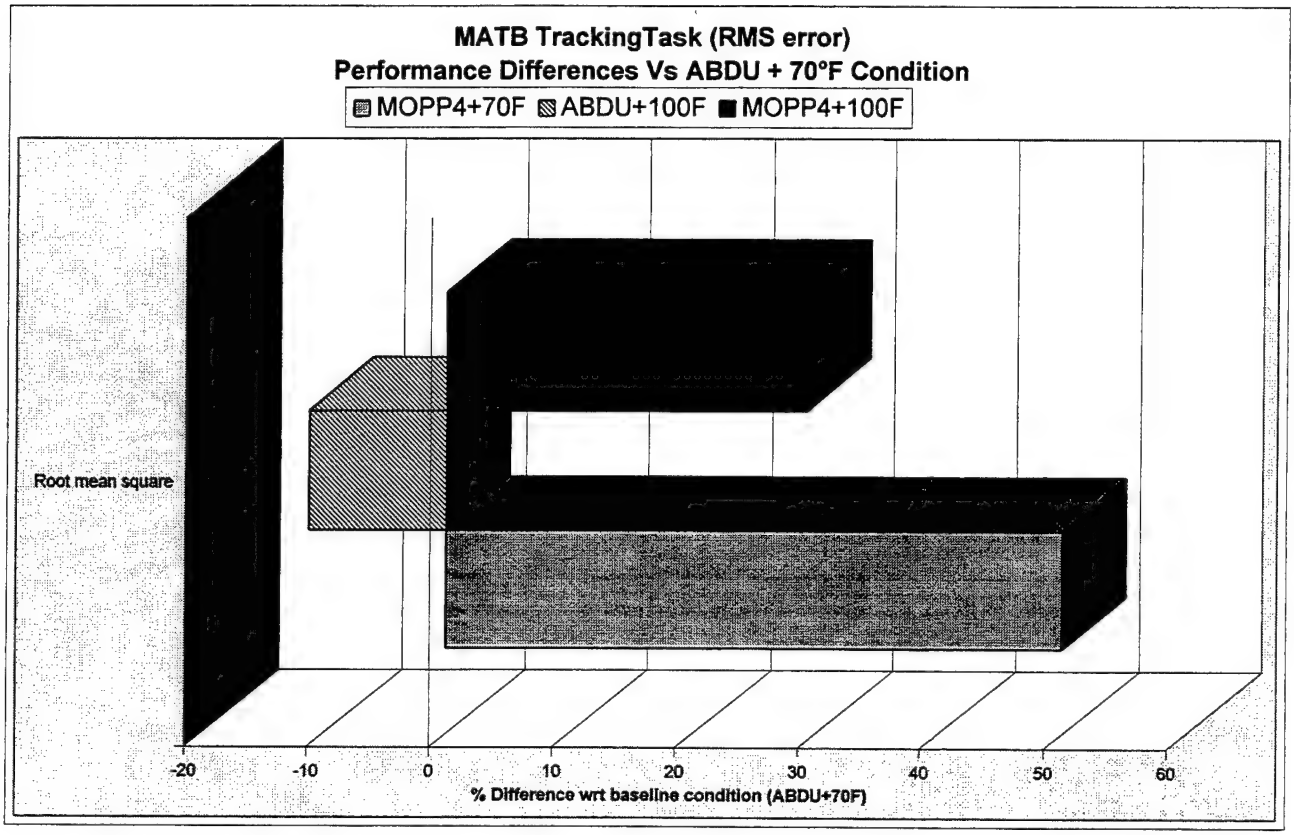


Table F-2.

MATB: Performance on the tracking and fuel management tasks.



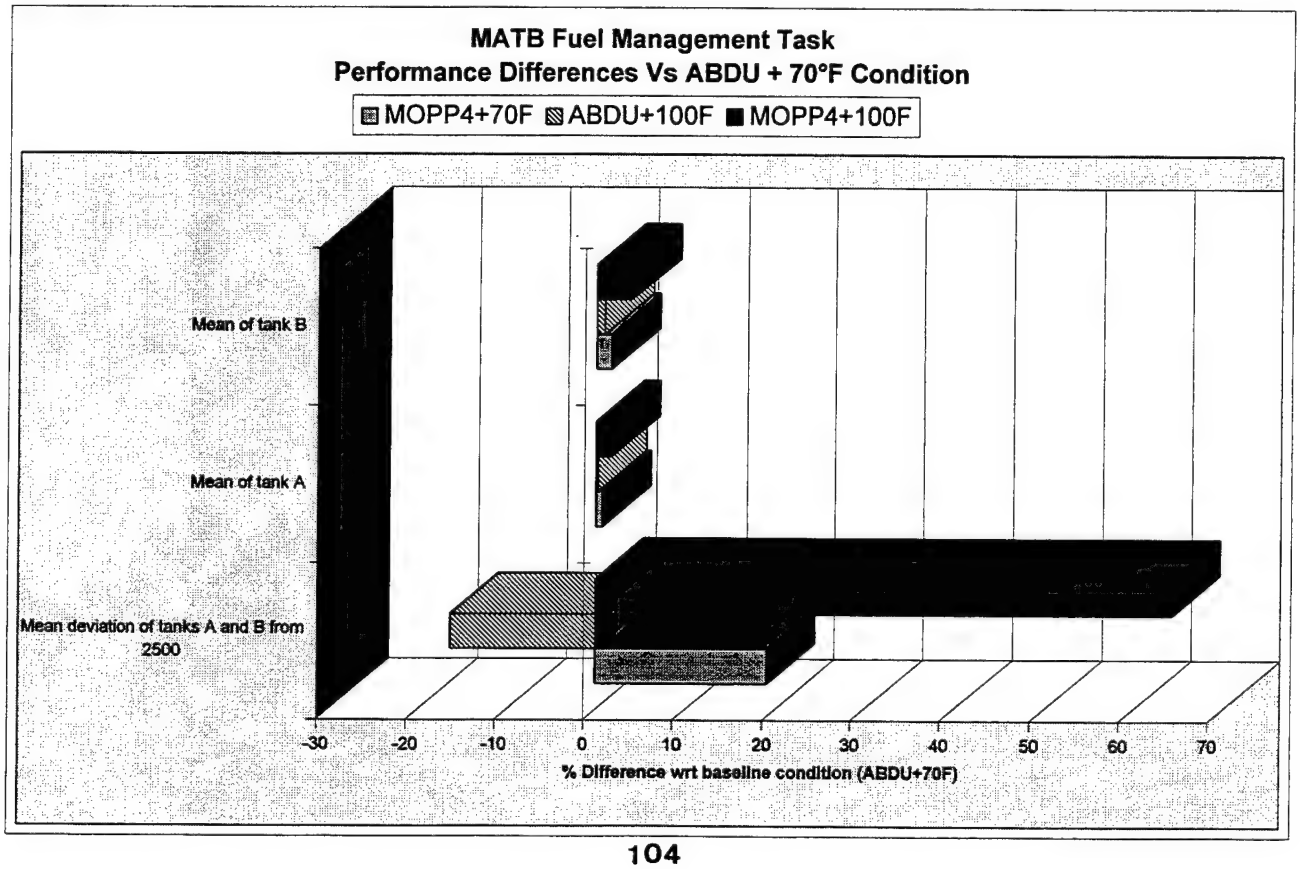


Table F-3.

Repeated measures ANOVA results for multi-attribute task battery.

MEAN MATB SCORES BY CONDITION							MAIN EFFECTS TEMPERATURE		MAIN EFFECTS UNIFORM		INTERACTION TEMPERATURE X UNIFORM	
EVENT	EVENT DESCRIPTION	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F	F VALUE	P VALUE	F VALUE	P VALUE	F VALUE	P VALUE
COMMUNICATION												
COMCRT	Mean response time for correct responses	8	5.40	6.39	5.39	4.78	17.29	0.0060	0.45	0.5280	14.24	0.0092
COMCSD	Standard deviation for correct responses	8	2.06	2.19	2.07	1.35	6.08	0.0487	1.15	0.3255	13.55	0.0103
COMORT	Mean overall response time	8	5.31	6.39	5.37	4.85	9.80	0.0203	0.85	0.3914	15.80	0.0073
COMOSD	Standard deviation for overall responses	8	2.16	2.26	2.15	1.41	6.75	0.0408	1.35	0.2898	14.18	0.0093
COMER	Total number of errors	8	0.57	0.98	0.64	0.21	8.37	0.0276	0.00	0.9597	13.39	0.0106
COMYFA	Othership false alarms	8	0.00	0.00	0.00	0.00	–	–	–	–	–	–
COMYAC	Othership accuracy errors	8	0.00	0.00	0.00	0.00	–	–	–	–	–	–
COMYIG	Othership messages correctly ignored	8	3.00	3.00	3.00	3.00	–	–	–	–	–	–
COMAC	Accuracy errors	8	0.38	0.50	0.32	0.21	32.82	0.0012	0.01	0.9309	1.79	0.2292
COMTO	Time out errors	8	0.14	0.25	0.25	0.00	0.68	0.4416	1.04	0.3476	7.02	0.0381
COMUNER	Unexplained errors	8	0.05	0.23	0.07	0.00	4.50	0.0781	2.08	0.1996	8.40	0.0274
COMRPT	Repeated enters	8	0.20	0.41	0.09	0.36	1.17	0.3213	5.09	0.0650	0.16	0.7073
LIGHTS and DIALS												
LTSRT	Mean response time for lights	8	2.26	2.77	2.10	2.16	13.07	0.0086	6.18	0.0418	5.25	0.0557
DLSRT	Mean response time for dials	8	4.02	5.30	4.48	4.29	2.75	0.1413	9.06	0.0197	10.44	0.0144
MONRT	Mean response time for lights and dials	8	3.01	3.86	3.15	3.11	19.33	0.0032	10.68	0.0137	12.27	0.0100
LTSSD	Standard deviation for lights	8	1.64	1.98	1.45	1.24	11.14	0.0126	0.11	0.7455	2.24	0.1785
DLSSD	Standard deviation for dials	8	3.07	3.90	3.56	2.96	0.78	0.4072	0.55	0.4810	8.08	0.0249
MONSD	Standard deviation for lights and dials	8	2.62	3.33	3.01	2.49	2.25	0.1771	0.46	0.5175	9.54	0.0176
LTSTO	Time out errors for lights	8	0.08	0.14	0.21	0.13	0.75	0.4139	0.02	0.8955	0.81	0.3974
DLSTO	Time out error for dials	8	0.77	0.92	0.44	0.25	7.50	0.0290	0.04	0.8417	3.87	0.0899
MONTO	Time out errors for lights and dials	8	0.84	1.06	0.65	0.38	6.24	0.0411	0.03	0.8574	3.95	0.0871
LTSFA	False alarm errors for lights	8	0.09	0.33	0.17	0.19	0.64	0.4512	1.10	0.3295	1.96	0.2042
DLSFA	False alarm errors for dials	8	0.47	2.14	0.53	1.66	2.42	0.1639	4.62	0.0688	2.62	0.1499
MONFA	False alarm errors for lights and dials	8	0.56	2.47	0.70	1.84	2.29	0.1738	4.59	0.0693	3.01	0.1265
LTSER	Time out and false alarm errors for lights	8	0.18	0.54	0.42	0.36	0.10	0.7653	0.65	0.4516	2.64	0.1556
DLSER	Time out and false alarm errors for dials	8	1.21	3.30	0.95	2.04	8.96	0.0242	4.56	0.0767	3.67	0.1038
MONER	Time out and false alarm errors for lights and dials	8	1.39	3.84	1.36	2.39	7.45	0.0342	4.30	0.0834	4.19	0.0867
RESOURCE MANAGEMENT												
TNKMAD	Mean absolute deviation of tanks A and B from 2500	8	163.72	200.77	140.53	280.34	0.24	0.6417	1.06	0.3421	0.71	0.4308
TNKAMN	Mean of tank A	8	2530.15	2551.84	2537.22	2581.32	1.08	0.3389	0.82	0.3990	0.26	0.6296
TNKBMN	Mean of tank B	8	2511.61	2560.16	2538.24	2623.08	1.57	0.2563	1.70	0.2397	0.17	0.6954
TRKRMS	Root mean square	8	28.20	47.17	26.85	40.89	5.34	0.0602	9.96	0.0197	1.61	0.25

Table F-4.
MATB scripts.

Parameters: 0 00 manual '2 mon/min, track med, 1 msg/1 min w/.7 ownship.

0 00 manual - 10 minute time scale; **'2mon/min** - 2 monitoring tasks per minute; **track med** - tracking set at 48, medium difficulty level; **1 msg/1 min** - one communication message per minute; **w/.7 ownship** - 7 messages to respond to

1	2	3	4	5	6	7	8
0 00 tracking medium	0 00 tracking medium	0 00 tracking medium	0 00 tracking medium	0 00 tracking medium	0 00 tracking medium	0 00 tracking medium	0 00 tracking medium
0 10 scale 1 up	0 08 scale 1 up	0 10 scale 2 up	0 11 scale 3 up	0 12 scale 3 up	0 10 scale 4 up	0 11 scale 1 up	0 09 scale 4 up
0 25 comm task m1	0 24 comm task m1	0 23 comm task m13	0 22 comm task m2	0 23 comm task y13	0 22 comm task m14	0 21 comm task m14	0 19 comm task m15
0 40 red	0 40 red	0 41 red	0 41 red	0 40 red	0 40 red	0 40 red	0 36 red
1 05 green	1 07 green		1 02 green	1 01 green	1 01 green	1 01 green	1 07 green
1 30 scale 4 up	1 28 scale 3 up	1 26 scale 3 up	1 25 scale 2 up	1 26 scale 3 up	1 27 scale 2 up	1 24 scale 4 up	1 19 scale 2 up
1 35 comm task y1	1 34 comm task y1	1 35 comm task m1	1 33 comm task m10	1 34 comm task m11	1 33 comm task m12	1 34 comm task m9	1 34 comm task m4
1 55 green	1 55 green	1 56 green	1 55 green	1 54 green	1 55 green	1 55 green	1 57 green
2 25 scale 3 down	2 27 scale 4 down	2 29 scale 3 down	2 28 scale 2 down	2 29 scale 3 down	2 30 scale 4 down	2 23 scale 2 down	2 33 scale 4 down
2 40 comm task m2	2 42 comm task m12	2 42 comm task m12	2 44 comm task m12	2 45 comm task m13	2 43 comm task m14	2 43 comm task m14	2 53 comm task m6
3 00 scale 2 down	3 08 scale 1 down	3 11 scale 2 down	3 13 scale 1 down	3 12 scale 2 down	3 10 scale 1 down	3 09 scale 2 down	3 09 scale 1 down
3 25 red	3 12 red	3 13 red	3 15 red	3 16 red	3 15 red	3 14 red	3 13 red
3 30 comm task m3	3 30 comm task m3	3 31 comm task m3	3 34 comm task y3	3 35 comm task y4	3 37 comm task y7	3 39 comm task y7	3 43 comm task y11
4 00 red	4 02 red	4 03 red	4 04 red	4 04 red	4 04 red	4 04 red	4 14 red
4 20 scale 2 down	4 21 scale 3 down	4 20 scale 3 down	4 22 scale 2 down	4 21 scale 3 down	4 22 scale 2 down	4 21 scale 3 down	4 23 scale 2 down
4 45 comm task y2	4 44 comm task y2	4 45 comm task m2	4 44 comm task m3	4 43 comm task m4	4 43 comm task m6	4 42 comm task m6	4 47 comm task m9
4 55 green	4 53 green	4 52 green	4 51 green	4 51 green	4 51 green	4 50 green	4 58 green
5 25 comm task m4	5 21 comm task m4	5 21 comm task y4	5 20 comm task y14	5 19 comm task m15	5 20 comm task y11	5 21 comm task y11	5 19 comm task y15
5 40 scale 2 down	5 41 scale 2 down	5 42 scale 1 down	5 43 scale 2 down	5 42 scale 3 down	5 42 scale 4 down	5 42 scale 3 down	5 37 scale 4 down
6 00 red	6 02 red	6 01 red	6 00 red	6 02 red	6 00 red	6 02 red	6 06 red
6 25 green	6 27 green	6 27 green	6 29 green	6 28 green	6 27 green	6 26 green	6 23 green
6 30 comm task m13	6 31 comm task m7	6 30 comm task y7	6 30 comm task m8	6 31 comm task y9	6 32 comm task y8	6 32 comm task m8	6 37 comm task m2
7 05 green	7 07 green	7 06 green	7 07 green	7 06 green	7 06 green	7 03 green	7 05 green
7 30 scale 1 up	7 32 scale 2 up	7 33 scale 1 up	7 31 scale 2 up	7 32 scale 3 up	7 33 scale 4 up	7 37 scale 3 up	7 25 scale 2 up
7 40 comm task y4	7 39 comm task y4	7 38 comm task m4	7 39 comm task m7	7 38 comm task m8	7 39 comm task m9	7 39 comm task m9	7 39 comm task m10
7 55 red	7 54 red	7 54 red	7 54 red	7 53 red	7 52 red	7 53 red	7 57 red
8 25 comm task m5	8 26 comm task m5	8 25 comm task y5	8 25 comm task y8	8 27 comm task m9	8 28 comm task m10	8 26 comm task y10	8 22 comm task y1
8 30 scale 3 down	8 31 scale 4 down	8 33 scale 3 down	8 34 scale 2 down	8 34 scale 1 down	8 33 scale 3 down	8 33 scale 2 down	8 35 scale 4 down
9 07 scale 4 down	9 09 scale 2 down	9 08 scale 1 down	9 10 scale 3 down	9 09 scale 4 down	9 11 scale 2 down	9 13 scale 3 down	9 11 scale 1 down
9 25 comm task m15	9 24 comm task m15	9 22 comm task m5	9 24 comm task m6	9 26 comm task m7	9 26 comm task m2	9 26 comm task m2	9 26 comm task m3
9 35 green	9 37 green	9 36 green	9 35 green	9 35 green	9 35 green	9 35 green	9 35 green
10 00 end	10 00 end	10 00 end	10 00 end	10 00 end	10 00 end	10 00 end	10 00 end

0 minutes; 00 seconds.

Monitoring task: simulated strip guage # 3 deviates more than 2 units up or down from the midpoint; user must detect and enter keyboard response.

Monitoring task: simulated strip guage # 2 deviates more than 2 units up or down from the midpoint user must detect and enter the appropriate keyboard response

Communication task: simulated ATC command for user's (m) aircraft; user must comply by entering new commo channel or frequency via the keyboard.

Communication task: simulated ATC command for another (y) aircraft; user should ignore.

Warning lights: green light goes off; user must detect and hit corresponding key to turn it back on.

Warning lights: red light comes on; user must detect and hit corresponding key to turn it off.

Tracking: medium difficulty setting (48).

Appendix G. TLX questionnaire.

Table G-1.

ANOVA results for task load index across task.

MEANS OF TLX QUESTIONAIRE BY CONDITION

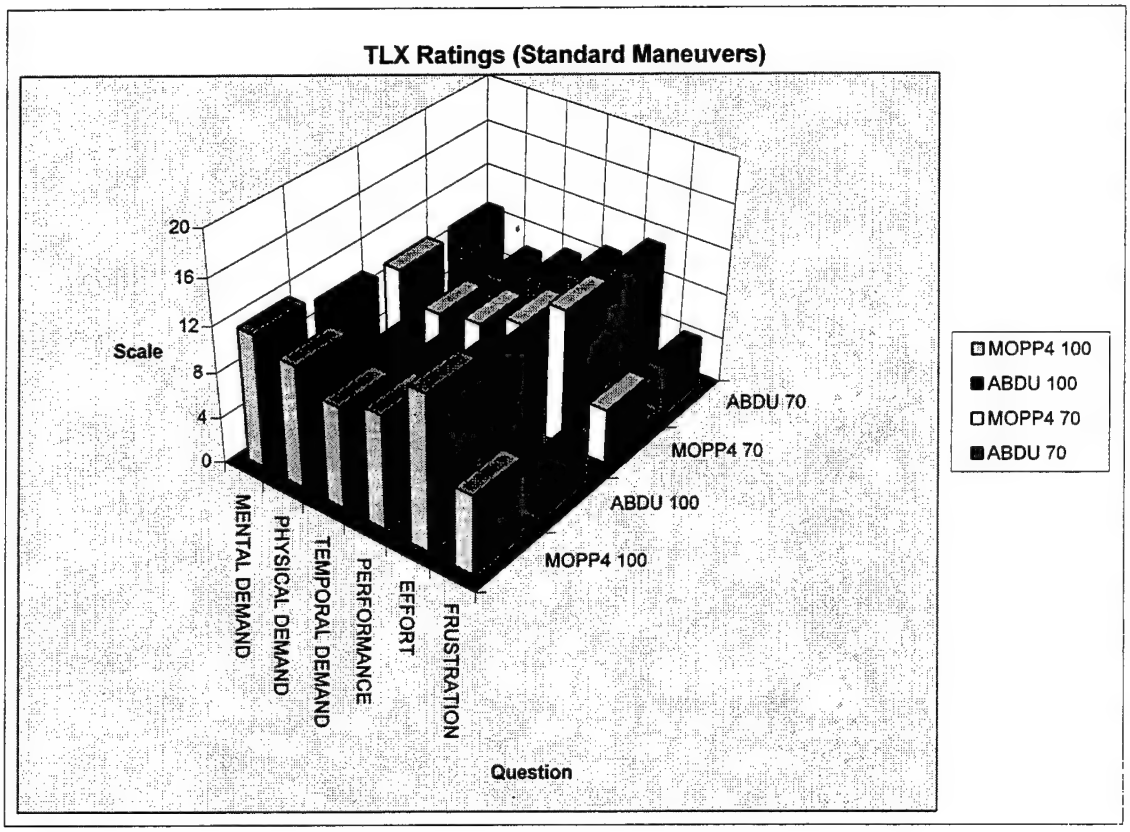
QUESTION	NUM TSs	ABDU, 70°F	MOPP4, 70°F	ABDU, 100°F	MOPP4, 100°F
MENTAL DEMAND					
TASK 1: STANDARD MANEUVERS	9	9.1875	9.49	10.16	11.69
TASK 2 : MATB	8	8.375	9.87	9.09	10.17
TASK 1 AND TASK 2	17	8.78125	9.68	9.63	10.93
PHYSICAL DEMAND					
TASK 1: STANDARD MANEUVERS	9	6.31	6.62	6.91	10.67
TASK 2 : MATB	8	4.16	5.70	4.65	6.83
TASK 1 AND TASK 2	17	5.23	6.16	5.78	8.75
TEMPORAL DEMAND					
TASK 1: STANDARD MANEUVERS	9	7.31	7.25	7.22	8.85
TASK 2 : MATB	8	7.06	8.67	7.39	9.08
TASK 1 AND TASK 2	17	7.19	7.96	7.31	8.97
PERFORMANCE					
TASK 1: STANDARD MANEUVERS	9	9.38	9.32	8.88	9.92
TASK 2 : MATB	8	7.69	9.20	7.27	8.42
TASK 1 AND TASK 2	17	8.53	9.26	8.07	9.17
EFFORT					
TASK 1: STANDARD MANEUVERS	9	10.94	11.74	11.38	13.42
TASK 2 : MATB	8	9.38	11.18	10.28	11.96
TASK 1 AND TASK 2	17	10.16	11.46	10.83	12.69
FRUSTRATION					
TASK 1: STANDARD MANEUVERS	9	3.72	4.06	3.69	6.85
TASK 2 : MATB	8	3.45	5.65	2.82	4.29
TASK 1 AND TASK 2	17	3.59	4.85	3.25	5.57

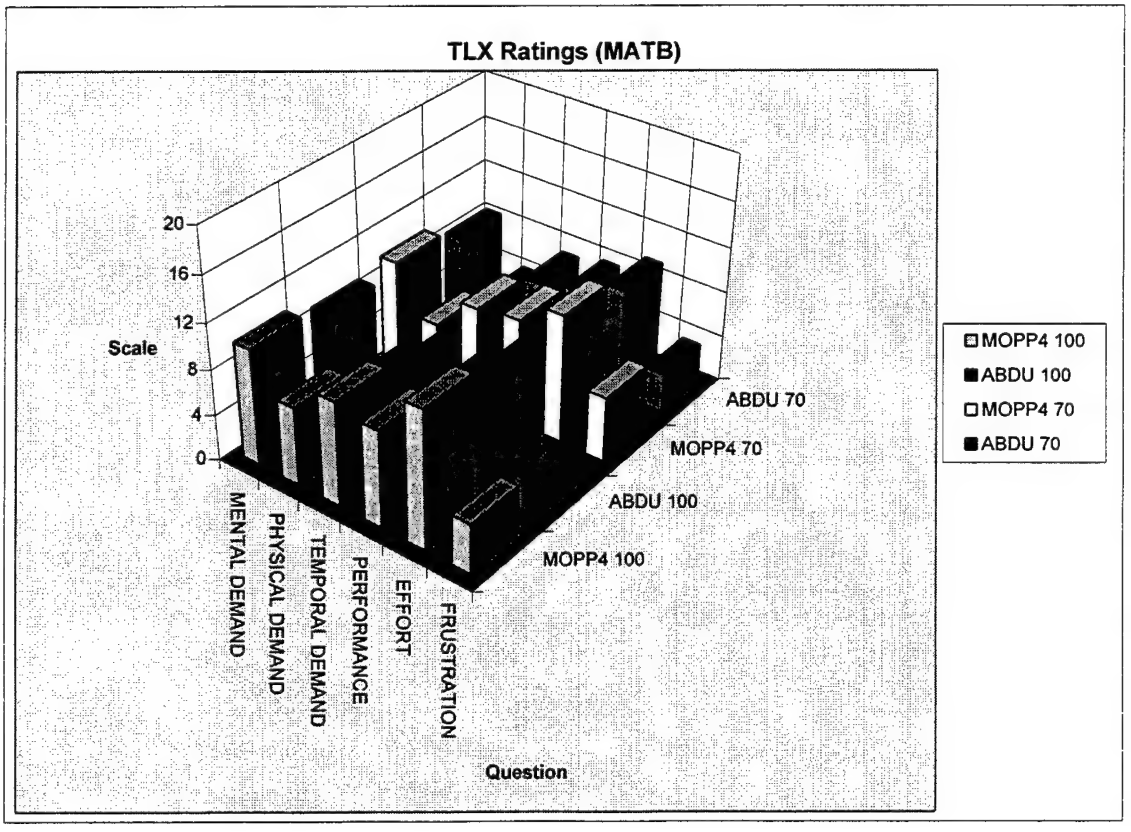
	MAIN EFFECTS					
	TASK		TEMPERATURE		UNIFORM	
QUESTION	F VALUE(1,14)	P VALUE	F VALUE(1,14)	P VALUE	F VALUE(1,14)	P VALUE
MENTAL DEMAND	0.16	0.6944	5.13	0.0393*	7.54	0.0158*
PHYSICAL DEMAND	1.81	0.2004	29.13	0.0001*	11.38	0.0046*
TEMPORAL DEMAND	0.04	0.8429	3.75	0.0732	9.62	0.0078*
PERFORMANCE	0.82	0.3791	0.43	0.5236	4.13	0.0615
EFFORT	0.26	0.6159	5.63	0.0325*	14.88	0.0017*
FRUSTRATION	0.13	0.7239	0.10	0.7507	5.99	0.0282*

	INTERACTION TASK X TEMPERATURE		INTERACTION TASK X UNIFORM		INTERACTION TEMPERATURE X UNIFORM		INTERACTION TASK X TEMPERATURE X UNIFORM	
QUESTION	F VALUE(1,14)	P VALUE	F VALUE(1,14)	P VALUE	F VALUE(1,14)	P VALUE	F VALUE(1,14)	P VALUE
MENTAL DEMAND	1.35	0.2849	0.21	0.6560	0.33	0.5739	1.37	0.2613
PHYSICAL DEMAND	6.75	0.0210*	0.02	0.8881	10.39	0.0061*	4.91	0.0438*
TEMPORAL DEMAND	0.44	0.5183	1.21	0.2896	1.35	0.2651	1.12	0.3071
PERFORMANCE	0.59	0.4558	0.87	0.3679	0.29	0.6013	1.13	0.3061
EFFORT	0.07	0.7935	0.15	0.7043	0.85	0.3718	1.28	0.2764
FRUSTRATION	3.93	0.0674*	0.00	0.9572	0.76	0.3983	2.16	0.1637

Table G-2.

Tlx ratings across task.





Appendix H. Correlation tables.

Table H-1.
Correlations of ACS and aviator demographics.

Marked correlations are significant at P≤.05

	AGE	HEIGHT	WEIGHT	PT SCORE	HEAT STRESS TRAINING	TOTAL FLIGHT TIME	UH60 FLIGHT TIME	TOTAL SIMULATED FLIGHT	UNIFORM	TEMPERATURE
ACS HOVER TURN	-0.0768	0.2043	-0.0273	-0.1517	0.1194	-0.1487	-0.4357	-0.2819	-0.4902	0.0555
ACS RSRT	0.0001	0.0431	0.0306	-0.1894	0.1773	0.1485	-0.1391	-0.1581	-0.3175	-0.2079
ACS LCT	-0.3807	0.4602	0.1217	-0.3016	0.1122	-0.4495	-0.6389	-0.4001	-0.0557	0.0255
ACS SL	-0.1617	0.3583	0.3852	-0.5181	0.1266	-0.0580	-0.2532	-0.1714	-0.2659	-0.0645
ACS LDT	-0.3598	0.1783	-0.0060	-0.2454	0.2020	-0.1357	-0.2200	-0.0410	-0.0038	-0.0610
ACS NOE	-0.2949	0.2824	0.3277	-0.2941	0.0085	-0.1961	-0.0902	-0.0277	-0.1936	0.0104
ACS CONTOUR	-0.3537	0.3254	0.2596	-0.3314	0.0506	-0.2881	-0.1738	-0.0065	-0.4550	-0.0101
ACS HOVER	0.1085	-0.2819	-0.3293	0.0234	-0.1199	-0.0400	0.0228	0.0977	0.1743	-0.1689

Table H-2.

Correlations of flight data: ACS scores and aviator demographics-divided by condition.

MOPP0, 70°F

Marked correlations are significant at p<.05

	AGE	WEIGHT	HEIGHT	PT SCORE	HS TRAINING	TOT FLIGHT	UH60 FLIGHT	TOT SIM
HOVER	-0.7856	0.1290	0.0163	-0.6799	0.4430	-0.0881	-0.0039	0.2518
HOVT	-0.2513	0.5181	0.1244	-0.4825	0.2310	-0.4096	-0.7185	-0.3092
RSRT	0.5283	-0.1000	-0.3197	0.1447	0.0719	0.1635	-0.3959	-0.3702
LCT	-0.3074	0.4918	0.0446	-0.1609	0.0992	-0.3562	-0.8369	-0.7011
SL	-0.2114	0.5790	0.3901	-0.3743	-0.0637	-0.4327	-0.7203	-0.5388
LDT	-0.5029	-0.7078	0.1696	-0.3075	0.3496	-0.3770	-0.7661	-0.3661
NOE	0.4762	-0.3395	-0.2615	0.6508	-0.0636	0.4685	0.4060	0.1051
CONT	-0.1395	0.2428	0.4083	0.2929	-0.5245	-0.6683	0.0546	0.0081

MOPP4, 70°F

Marked correlations are significant at p<.05

	AGE	WEIGHT	HEIGHT	PT SCORE	HS TRAINING	TOT FLIGHT	UH60 FLIGHT	TOT SIM
HOVER	-0.6267	-0.2754	-0.1392	-0.6095	0.2784	0.2095	0.3085	0.3307
HOVT	-0.2014	-0.1020	0.0937	-0.3669	0.0253	-0.2560	0.0059	0.1545
RSRT	-0.4588	0.3063	0.3958	-0.6444	0.2175	-0.1538	-0.2345	-0.0461
LCT	-0.5070	0.3920	-0.0720	-0.0862	-0.1506	-0.7588	-0.5780	-0.3262
SL	-0.4601	0.1043	0.3927	-0.5271	0.1504	0.1822	0.0167	-0.0921
LDT	-0.6085	-0.0643	0.3206	-0.3793	-0.0080	-0.0300	0.4513	0.4885
NOE	-0.1276	0.4070	0.7205	-0.4045	-0.4322	-0.4084	-0.3257	-0.3966
CONT	-0.2021	0.5753	0.4564	-0.6556	0.0724	-0.2122	-0.5853	-0.4186

MOPP0, 100°F

Marked correlations are significant at p<.05

	AGE	WEIGHT	HEIGHT	PT SCORE	HS TRAINING	TOT FLIGHT	UH60 FLIGHT	TOT SIM
HOVER	-0.4850	-0.3027	-0.0512	-0.4654	-0.0005	0.0672	0.5225	0.5223
HOVT	-0.0715	0.6655	0.1674	-0.1529	0.3413	0.0703	-0.5701	-0.8146
RSRT	0.2125	0.3536	-0.0338	-0.0629	0.2018	-0.0644	-0.7539	-0.6274
LCT	-0.2464	0.5452	0.0122	0.0370	0.1406	-0.5035	-0.8695	-0.5851
SL	-0.1535	0.5750	0.5663	-0.6571	0.0668	-0.3416	-0.4082	-0.1221
LDT	-0.7524	0.2942	-0.0112	-0.3567	0.2743	-0.5346	-0.2732	0.1861
NOE	-0.6297	0.2911	-0.1017	-0.2199	0.2119	-0.3543	-0.3389	-0.0788
CONT	-0.3579	0.2019	0.2460	-0.6160	0.1731	-0.2376	0.1409	0.5374

MOPP4, 100°F

Marked correlations are significant at p<.05

	AGE	WEIGHT	HEIGHT	PT SCORE	HS TRAINING	TOT FLIGHT	UH60 FLIGHT	TOT SIM
HOVER	-0.5346	0.6081	0.0077	0.0237	0.5935	-0.6848	-0.6160	-0.2373
HOVT	0.0013	0.0366	-0.1947	0.1343	-0.0806	-0.3489	-0.4514	-0.3422
RSRT	-0.2293	-0.0239	0.2946	-0.2924	0.2936	0.4729	0.2718	0.0125
LCT	-0.5068	0.5252	0.2466	-0.7079	0.2456	-0.6352	-0.5920	-0.2696
SL	-0.1658	0.4261	0.5094	-0.7573	0.2287	-0.0102	-0.2383	-0.1902
LDT	0.1664	-0.5769	-0.6353	-0.0611	-0.0240	0.2918	-0.0512	-0.0527
NOE	-0.6233	0.4754	0.6099	-0.7011	0.2485	-0.5209	0.0246	0.2745
CONT	-0.8085	0.5767	0.3209	-0.3402	0.1610	-0.7423	-0.3779	-0.2140

Table H-3.

Correlations of TLX questionnaire data vs. ACS scores across all conditions.

Marked correlations are significant at p≤ .05

	TEMPERATURE	ACS HOVER	ACS HOVER TURN	ACS RSRT	ACS LCT	ACS SL	ACS LDT	ACS NOE	ACS CONTOUR
MENTAL DEMAND	0.1892	0.1697	0.0881	-0.3488	-0.0884	-0.4698	0.1078	-0.2492	-0.2031
PHYSICAL DEMAND	0.2676	0.1084	-0.1217	-0.4781	-0.2650	-0.4997	0.0107	-0.2658	-0.2911
TEMPORAL DEMAND	0.0708	0.0934	0.2053	-0.2191	-0.0598	-0.2954	0.1138	-0.2267	-0.2851
PERFORMANCE	0.0163	0.3282	-0.0045	-0.1965	0.0133	-0.1192	-0.1614	0.0340	-0.1632
EFFORT	0.0942	0.2778	0.0432	-0.3202	-0.1299	-0.3736	0.0413	-0.2069	-0.1660
FRUSTRATION	0.1400	-0.1382	-0.3648	-0.3497	-0.1689	-0.1326	-0.2488	0.1506	-0.2653
UNIFORM	-0.0294	0.1743	-0.4902	-0.3175	-0.0557	-0.2659	-0.0038	-0.1936	-0.4550

Table H-4.
Correlations of TLX data vs. ACS scores.

MOPP0, 70°F

Marked correlations are significant at p < .05000

	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration
Hover	0.0847	0.4108	0.3227	-0.2530	-0.0099	-0.4925
Hover Turn	0.0010	0.3381	-0.0725	-0.2064	-0.0280	0.4395
Right Standard Rate Turn	0.2102	0.0628	-0.2304	0.5183	0.1010	0.8526
Left Climbing Turn	-0.0885	0.1178	-0.2462	-0.3534	-0.2439	0.2937
Straight and Level	0.0112	0.1579	-0.0771	-0.2980	-0.0719	0.4564
Left Descending Turn	-0.3537	-0.0888	-0.3764	-0.3617	-0.3294	0.0835
Nap Of Earth	-0.2377	-0.5043	-0.2503	0.1984	-0.1328	-0.1906
Contour	-0.3009	-0.0786	-0.0338	-0.6779	-0.1491	-0.3596

MOPP4, 70°F

Marked correlations are significant at p < .05000

	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration
Hover	0.5293	0.5297	0.6691	-0.1058	0.4637	-0.2134
Hover Turn	0.0626	0.3988	-0.0429	0.2285	-0.0275	0.8166
Right Standard Rate Turn	-0.0480	0.2967	0.0118	-0.0064	-0.2184	0.6648
Left Climbing Turn	0.4882	0.3760	0.2990	-0.6290	0.1987	-0.1342
Straight and Level	0.0321	0.2292	0.2374	-0.2102	-0.1375	0.1877
Left Descending Turn	0.0022	-0.1252	0.3846	-0.2433	0.2215	-0.3974
Nap Of Earth	0.3817	0.5254	0.4912	-0.6784	0.1452	-0.0444
Contour	0.3529	0.6081	0.3443	-0.3453	0.0363	0.2285

MOPP0, 100°F

Marked correlations are significant at p < .05000

	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration
Hover	0.3335	0.3989	0.7086	-0.1963	0.4257	-0.6770
Hover Turn	-0.2976	-0.0440	-0.3219	-0.4472	-0.3774	0.1848
Right Standard Rate Turn	-0.0210	0.1257	-0.2785	0.0822	-0.1150	0.7706
Left Climbing Turn	-0.2040	-0.0150	-0.4518	-0.1626	-0.3352	0.5282
Straight and Level	-0.0372	0.2637	0.2220	-0.2719	0.0525	0.0703
Left Descending Turn	-0.0862	0.0968	-0.0342	-0.0854	-0.1039	-0.0502
Nap Of Earth	-0.0662	0.1930	0.0844	-0.5873	-0.0431	-0.4500
Contour	0.0294	0.2210	0.3585	-0.1648	0.2164	-0.5756

MOPP4, 100°F

Marked correlations are significant at p < .05000

	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration
Hover	-0.6833	-0.3216	-0.6742	-0.3075	-0.6314	0.4448
Hover Turn	0.1027	0.2957	-0.3684	-0.0693	-0.1583	-0.1279
Right Standard Rate Turn	-0.1045	-0.1604	0.1057	0.1123	-0.1442	-0.2308
Left Climbing Turn	0.1090	0.4168	0.0925	-0.3329	0.1194	0.0645
Straight and Level	0.0812	0.2278	0.2362	-0.1244	0.1721	-0.1202
Left Descending Turn	0.7188	0.7389	0.2608	0.3564	0.5315	-0.0953
Nap Of Earth	-0.3118	-0.0407	0.0894	-0.1133	-0.2009	0.2658
Contour	-0.2229	-0.1460	0.0420	-0.6531	-0.1986	-0.0256

Table H-5.

Correlations of flight data: ACS scores vs. MATB in all conditions.

Marked correlations are significant at p<.05

	HOVER	HOVT	RSRT	LCT	SL	LDT	NOE	CONT
COMCRT	0.1883	0.0327	* 0.5204	0.2491	* 0.5121	-0.2172	0.3708	0.2069
COMCSD	0.3808	0.2421	* 0.6355	0.1401	0.3334	-0.2828	0.2498	0.1377
COMORT	0.1637	0.0181	* 0.5064	0.2129	* 0.4865	-0.2528	0.3593	0.1616
COMOSD	0.3578	0.2300	* 0.5908	0.0678	0.3008	-0.2978	0.1964	0.1031
COMER	-0.0853	0.0079	-0.0807	* 0.4797	-0.3866	-0.3560	-0.1517	-0.1956
COMAC	-0.1485	0.0039	-0.3093	* 0.6778	* 0.5472	-0.2647	-0.3041	-0.4154
COMTO	-0.0088	0.0595	0.1542	-0.1829	-0.1736	-0.3444	0.0186	0.0037
COMUNER	-0.0319	-0.0805	-0.0104	-0.2300	-0.1388	-0.2349	-0.0451	0.0183
COMRPT	-0.1333	-0.2110	0.3897	0.3454	* 0.5778	0.1171	0.3873	0.0533
LTSRT	0.2764	-0.1152	0.2370	-0.0941	0.2914	-0.1143	0.2089	0.2490
DLSRT	0.0639	-0.2665	-0.0062	0.0610	0.1914	0.1019	0.3744	0.2027
MONRT	0.1852	-0.2332	0.1081	-0.0049	0.2787	0.0164	0.3369	0.2666
LTSSD	* 0.5048	0.1485	0.1487	-0.1558	0.0517	-0.0794	0.1698	* 0.4829
DLSSD	0.1338	0.1858	0.0214	-0.0107	-0.0482	0.3858	0.1963	0.0880
MONSD	0.2930	0.2003	0.0448	0.0123	0.0172	0.3061	0.3262	0.2820
LTSTO	0.1685	-0.3323	-0.1429	0.1118	-0.0050	-0.1466	0.0102	* 0.4744
DLSTO	0.2760	0.1461	* 0.4298	-0.1986	-0.0441	-0.3291	0.1663	0.0709
MONTO	0.3294	-0.0642	0.2835	-0.1051	-0.0402	-0.3620	0.1468	0.3287
LTSFA	0.1088	-0.1177	0.1357	-0.2757	-0.0143	-0.1448	-0.0062	0.0275
DLSFA	0.0961	-0.2634	0.2772	-0.1194	0.1470	0.1968	-0.1552	-0.1225
MONFA	0.1047	-0.2609	0.2763	-0.1505	0.1341	0.1613	-0.1446	-0.1094
LTSER	0.0120	-0.1470	0.1346	0.0795	0.1877	-0.0564	* 0.6198	0.1080
DLSER	-0.3276	-0.1380	-0.2186	0.2399	0.0157	0.2735	0.3360	-0.1536
MONER	-0.2847	-0.1508	-0.1642	0.2264	0.0519	0.2283	0.4204	-0.1127
TRKRMS	-0.0320	* -0.6517	-0.1943	0.2737	0.0330	0.0137	0.3195	0.0421
TNKMAD	0.2220	-0.1526	0.0234	-0.2940	-0.0484	0.0766	0.0129	0.0411
TNKAMN	0.0781	0.0064	0.1788	-0.4101	0.0693	0.0590	-0.0747	-0.1813
TNKBMN	0.0987	-0.0716	0.0889	-0.3782	0.0228	0.0423	-0.1024	-0.1654

Table H-6.

Correlations of flight data: ACS scores vs. MATB.

(See variable descriptions on the next page.)

ABDU, 70°F

Marked correlations are significant at p < .05000

	HOV	HOVT	RSRT	LCT	SL	LDT	NOE	CONT
COMCRT	0.4054	0.8991	0.3006	0.3248	0.3517	-0.5422	-0.6807	-0.0405
COMCSD	0.4124	0.4771	0.5947	0.3705	-0.1061	-0.6914	-0.3885	-0.5562
COMORT	0.3413	0.8251	0.3611	0.2924	0.2718	-0.5946	-0.6056	-0.0536
COMOSD	0.4314	0.5632	0.5508	0.3792	-0.0327	-0.6765	-0.4490	-0.4746
COMER	0.8991	-0.1085	0.5426	-0.7531	-0.0923	-0.5683	0.2796	0.1361
COMAC	-0.6732	-0.0469	0.4613	-0.4463	0.0220	-0.5063	0.0899	0.1122
COMTO	-0.7684	-0.6178	0.5637	-0.6235	-0.7173	-0.4092	0.7920	-0.2348
COMUNER	-0.1338	0.6531	-0.1348	-0.3764	0.7143	-0.0680	-0.5094	0.4976
COMRPT	-0.2689	0.5169	0.2062	-0.3778	0.2904	-0.3802	-0.2243	0.3115
LTSRT	0.2737	0.3008	0.1220	0.1678	0.6703	-0.3862	-0.8164	0.1789
DLSRT	-0.0825	-0.0781	-0.5631	0.3395	0.1679	0.5053	0.0915	0.7913
MONRT	0.1824	0.6097	-0.3239	0.3820	0.6036	0.0801	-0.5466	0.6545
LTSSD	0.1489	0.6693	0.0204	0.2824	0.5428	-0.2581	-0.6194	0.3440
DLSSD	0.0607	-0.5483	-0.4915	0.4597	-0.3077	0.5954	0.4298	0.2918
MONSD	0.0217	-0.3358	-0.4788	0.4171	-0.0562	0.5093	0.2097	0.4177
LTSTO	0.2182	0.3096	-0.5078	0.1807	0.6851	0.4040	-0.5098	0.4163
DLSTO	-0.4928	0.0669	0.7842	-0.4182	-0.3005	0.8854	0.0854	-0.4527
MONTO	-0.4629	0.1586	0.7708	-0.3941	-0.1265	0.8528	-0.0530	-0.3643
LTSFA	-0.0634	0.6536	0.3708	-0.0493	0.1776	-0.5687	-0.3220	0.1810
DLSFA	-0.3203	-0.3130	0.8103	-0.5527	-0.4672	-0.6473	0.2725	0.6953
MONFA	-0.3219	-0.1685	0.7872	-0.5433	-0.4144	-0.7448	0.1972	-0.8017
LTSER	-0.7077	-0.5331	0.1472	-0.1832	-0.6352	-0.1055	0.8103	0.4171
DLSER	-0.8491	-0.2840	0.6316	-0.5945	-0.4937	-0.6133	0.5721	0.0383
MONER	-0.8559	-0.3528	0.5526	-0.5256	-0.5482	-0.5284	0.6518	0.1246
TRKRMS	0.0591	0.2323	-0.3564	0.5603	-0.0094	0.1754	0.0533	0.7988
TNKMAD	0.0348	-0.6778	-0.3685	-0.1012	-0.3579	0.6080	0.5143	-0.1819
TNKAMN	0.0334	-0.3768	0.0278	-0.3724	-0.2476	0.1719	0.2664	-0.5133
TNKBMN	0.3028	-0.2101	-0.1250	-0.1424	-0.1177	0.2869	0.0785	-0.4805

ABDU, 100°F

Marked correlations are significant at p < .05000

	HOV	HOVT	RSRT	LCT	SL	LDT	NOE	CONT
COMCRT	0.0631	0.8185	0.6561	0.0072	0.2608	-0.1164	0.6393	0.7120
COMCSD	0.5697	0.3167	0.8214	0.1119	0.7060	0.2015	0.6960	0.9396
COMORT	0.1468	0.8720	0.7173	0.0624	0.3182	-0.0689	0.6644	0.7601
COMOSD	0.4589	0.6255	0.8263	0.0374	0.6551	0.2102	0.7210	0.9136
COMER	-0.7367	0.1173	-0.4683	-0.2838	-0.7693	0.8860	-0.4934	-0.5225
COMAC	-0.7449	0.0879	-0.5095	-0.1175	-0.8166	0.8310	-0.3745	-0.4755
COMTO	-0.5835	0.1856	-0.4031	-0.2502	-0.6841	0.9081	-0.5242	-0.4624
COMUNER	-0.8666	0.0274	-0.4767	-0.4783	-0.8013	-0.8517	-0.5142	-0.6088
COMRPT	0.1048	0.8443	0.8188	-0.2322	0.4440	0.1847	0.8340	0.7180
LTSRT	-0.0094	0.7577	0.7221	-0.1611	0.3277	0.1864	0.6893	0.6739
DLSRT	-0.8038	-0.2459	-0.3185	-0.2312	-0.5658	-0.0019	0.0852	-0.3211
MONRT	-0.3962	0.3705	0.3458	-0.2274	-0.0347	0.1848	0.5344	0.3094
LTSSD	0.1664	0.9112	0.8538	-0.2596	0.4848	0.0874	0.5734	0.7291
DLSSD	0.5909	-0.1962	-0.5355	-0.4526	-0.8272	-0.5447	-0.3717	-0.6378
MONSD	0.0442	0.0623	-0.2184	-0.4494	-0.6087	-0.3606	-0.0565	-0.3207
LTSTO	0.2474	-0.0049	0.4557	-0.6120	0.5716	0.5936	-0.0419	0.1128
DLSTO	-0.1862	0.5823	0.1072	-0.4329	-0.1618	-0.8419	-0.4001	-0.0911
MONTO	-0.0928	0.6041	0.2976	-0.7005	0.0649	-0.8340	-0.4336	-0.0488
LTSFA	-0.4291	-0.1625	-0.1531	0.9365	-0.1757	-0.2611	-0.7388	-0.5960
DLSFA	0.5202	0.4704	0.4690	-0.4189	0.5378	-0.2049	-0.3394	0.1793
MONFA	0.4134	0.4117	0.4120	-0.5503	0.4725	-0.2350	-0.4406	0.0674
LTSER	0.1096	0.1472	0.5310	-0.1365	0.4456	0.7596	0.6124	0.4700
DLSER	0.1552	0.4777	0.8266	0.2319	0.3875	0.5443	0.9216	0.7572
MONER	0.1473	0.4010	0.6237	0.1346	0.4196	0.6290	0.8686	0.7041
TRKRMS	-0.0394	-0.5741	-0.2138	0.4535	-0.0480	0.7133	0.4369	0.0279
TNKMAD	0.0992	-0.3256	0.0778	-0.6741	0.3107	0.3759	-0.4513	-0.2926
TNKAMN	0.0464	-0.0531	0.2355	-0.8478	0.3354	0.2033	-0.4529	-0.2118
TNKBMN	0.0320	-0.0694	0.2418	-0.8354	0.3389	0.2549	-0.4071	-0.1959

MOPP4, 70°F

Marked correlations are significant at p < .05000

	HOV	HOVT	RSRT	LCT	SL	LDT	NOE	CONT
COMCRT	-0.2099	-0.0331	0.7489	0.2648	0.5376	-0.3498	-0.2405	-0.0475
COMCSD	-0.3410	-0.1045	0.8953	0.3127	0.2687	-0.4979	-0.3555	-0.3178
COMORT	-0.2131	0.0021	0.7826	0.2825	0.4822	-0.3741	-0.2298	-0.1107
COMOSD	-0.2952	-0.0954	0.8810	0.2849	0.2947	-0.4579	-0.3359	-0.2899
COMER	-0.0994	-0.2181	0.3360	-0.2555	-0.5990	-0.1659	-0.3494	-0.5830
COMAC	-0.0274	0.3832	0.8088	0.2756	-0.0894	-0.3582	0.0182	-0.5677
COMTO	-0.1251	-0.4227	0.0661	-0.3309	-0.6095	-0.0616	-0.3962	-0.4193
COMUNER	0.0306	0.0232	0.3145	-0.3987	-0.5301	-0.0961	-0.2444	-0.5237
COMRPT	0.6943	0.1763	-0.2920	0.2491	0.5890	0.6129	0.6505	0.5540
LTSRT	0.2607	-0.0597	0.2324	0.1274	0.6429	0.1962	0.1001	0.4648
DLSRT	0.0263	0.1878	-0.0489	0.2757	0.7431	0.0441	0.2102	0.5302
MONRT	0.1898	0.0237	0.0971	0.1858	0.8566	0.1735	0.1650	0.5505
LTSSD	0.4415	-0.0061	0.2005	0.1072	0.7228	0.3259	0.2237	0.4047
DLSSD	-0.0240	0.3548	0.3960	-0.3961	0.5484	-0.1469	-0.1866	0.1927
MONSD	0.4141	0.4684	0.1061	0.1799	0.6265	0.2292	0.4542	0.3473
LTSTO	0.3687	0.0548	0.3560	0.0495	0.6672	0.2106	0.1339	0.2795
DLSTO	-0.3614	0.2590	0.7675	-0.1885	-0.3228	-0.5707	-0.4150	-0.6603
MONTO	-0.1248	0.2418	0.8095	-0.1334	0.0505	-0.3746	-0.2816	-0.4162
LTSFA	-0.7259	0.2620	0.6097	0.5127	-0.1045	-0.9083	-0.3384	-0.6452
DLSFA	-0.6380	-0.2245	0.5979	-0.5307	-0.0314	-0.5970	-0.5411	-0.2868
MONFA	-0.7544	-0.1097	0.7742	-0.2913	-0.0578	-0.7743	-0.5200	-0.4350
LTSER	-0.2145	-0.1070	0.0208	0.3837	-0.8647	-0.2328	0.0225	-0.6864
DLSER	-0.0874	-0.7832	-0.5529	-0.5303	0.2250	0.2974	-0.4364	0.5778
MONER	-0.1462	-0.7795	-0.5150	-0.3858	-0.0510	0.2111	-0.4047	0.3406
TRKRMS	0.1127	0.4009	-0.1184	0.8190	-0.1645	-0.0144	0.6783	-0.1731
TNKMAD	-0.2068	0.5598	-0.1116	-0.3525	-0.2593	-0.2368	-0.0258	-0.1308
TNKAMN	-0.4329	0.1836	0.2083	-0.6242	-0.0868	-0.4045	-0.5210	-0.1299
TNKBMN	-0.5722	0.1745	0.2710	-0.5180	-0.0955	-0.5331	-0.5722	-0.1806

MOPP4, 100°F

Marked correlations are significant at p < .05000

	HOV	HOVT	RSRT	LCT	SL	LDT	NOE	CONT
COMCRT	-0.2229	-0.4024	0.8212	0.8385	0.8774	-0.2508	0.7644	0.1877
COMCSD	0.1391	-0.6813	0.9001	0.4444	0.6222	-0.3840	0.5441	0.2702
COMORT	-0.1810	-0.4800	0.7852	0.5120	0.8406	-0.3484	0.7141	0.1124
COMOSD	0.1572	-0.6874	0.7386	0.1187	0.7566	-0.5089	0.3683	0.0299
COMER	-0.1166	0.2919	-0.6381	0.8179	-0.6735	-0.0635	-0.6031	-0.7518
COMAC	-0.1166	0.2919	-0.6381	0.8179	-0.6735	-0.0635	-0.6031	-0.7518
COMTO	--	--	--	--	--	--	--	--
COMUNER	--	--	--	--	--	--	--	--
COMRPT	-0.3873	-0.1711	0.8524	0.6719	0.8127	0.0639	0.6346	0.0937
LTSRT	0.4706	-0.8026	0.4211	-0.2247	0.4063	-0.7127	0.1023	0.0317
DLSRT	-0.7124	0.1321	0.4308	0.4273	0.6748	-0.0113	0.6541	-0.2703
MONRT	-0.0963	-0.5059	0.5762	0.1380	0.7284	-0.5302	0.5111	-0.1128
LTSSD	0.8626	-0.4048	-0.4896	-0.3178	-0.5538	-0.4121	-0.3484	0.4734
DLSSD	-0.8395	0.9048	-0.1032	0.0900	-0.1761	0.9086	-0.1793	-0.4947
MONSD	-0.7316	0.8250	-0.2395	0.1648	-0.2724	0.8682	-0.1401	-0.3177
LTSTO	0.8696	-0.5538	-0.1433	0.1899	-0.1539	-0.3984	0.0353	0.8444
DLSTO	--	--	--	--	--	--	--	--
MONTO	0.8696	-0.5538	-0.1433	0.1899	-0.1539	-0.3984	0.0353	0.8444
LTSFA	--	--	--	--	--	--	--	--
DLSFA	-0.0952	0.0115	0.7283	0.0277	0.3496	0.5498	-0.3131	-0.1877
MONFA	-0.0952	0.0115	0.7283	0.0277	0.3496	0.5498	-0.3131	-0.1877
LTSER	-0.3162	-0.1948	0.0781	0.2848	0.4811	-0.5654	0.7469	-0.0389
DLSER	-0.8418	0.8300	-0.1845	0.3901	0.1210	0.2758	0.4879	-0.2470
MONER	-0.8120	0.5420	-0.1556	0.3973	0.1830	0.1643	0.5564	-0.2301
TRKRMS	0.3947	-0.8025	0.3701	0.5387	0.6664	-0.8344	0.8129	0.6469
TNKMAD	0.9456	-0.7949	-0.0965	-0.3600	-0.1510	-0.7445	-0.1811	0.3787
TNKAMN	-0.6187	0.2535	0.1785	-0.3741	0.1775	0.0947	-0.0625	-0.8367
TNKBMN	-0.2470	0.0053	0.0464	-0.6578	-0.0167	-0.1489	-0.3010	-0.7824

Table H-7.
MATB variable description.

COMCRT	Mean response time for correct responses
COMCSD	Standard deviation for correct responses
COMORT	Mean overall response time
COMOSD	Standard deviation for overall responses
COMER	Total number of errors
COMYFA	Othership false alarms
COMYAC	Othership accuracy errors
COMYIG	Othership messages correctly ignored
COMAC	Accuracy errors
COMTO	Time out errors
COMUNER	Unexplained errors
COMRPT	Repeated enters
LTSRT	Mean response time for lights
DLSRT	Mean response time for dials
MONRT	Mean response time for lights and dials
LTSSD	Standard deviation for lights
DLSSD	Standard deviation for dials
MONSD	Standard deviation for lights and dials
LTSTO	Time out errors for lights
DLSTO	Time out error for dials
MONTO	Time out errors for lights and dials
LTSFA	False alarm errors for lights
DLSFA	False alarm errors for dials
MONFA	False alarm errors for lights and dials
LTSER	Time out and false alarm errors for lights
DLSER	Time out and false alarm errors for dials
MONER	Time out and false alarm errors for lights and dials
TNKMAD	Mean absolute deviation of tanks A and B from 2500
TNKAMN	Mean of tank A
TNKBMN	Mean of tank B
TRKRMS	Root mean square

Appendix I. Data collection forms and procedures.

SIMULATOR FLIGHT INCIDENTS

Today's Date: _____ Cockpit Temp: _____°F Humidity: _____ Uniform: _____

	TS# __	TS# __	TS# ___	TS# ___	TS# ___	TS# ___
	Time into Mission & CoreTemp	Time into Mission & CoreTemp	Time into Mission & CoreTemp	Time into Mission & CoreTemp	Time into Mission & CoreTemp	Time into Mission & CoreTemp
TYPE OF INCIDENT	_____Hrs _____°C _____min	_____Hrs _____°C _____min	_____Hrs _____°C _____min	_____Hrs _____°C _____min	_____Hrs _____°C _____min	_____Hrs _____°C _____min
Crash						
during hover	❑	❑	❑	❑	❑	❑
attempting to land	❑	❑	❑	❑	❑	❑
flew into terrain	❑	❑	❑	❑	❑	❑
loss of control at alt	❑	❑	❑	❑	❑	❑
other	❑	❑	❑	❑	❑	❑
explanation						
Simulator sickness						
needed to transfer control	❑	❑	❑	❑	❑	❑
had to exit simulator	❑	❑	❑	❑	❑	❑
caused a crash	❑	❑	❑	❑	❑	❑
other	❑	❑	❑	❑	❑	❑
explanation						
Simulator malfunction						
electrical problem	❑	❑	❑	❑	❑	❑
mechanical "	❑	❑	❑	❑	❑	❑
computer "	❑	❑	❑	❑	❑	❑
navigational "	❑	❑	❑	❑	❑	❑
other	❑	❑	❑	❑	❑	❑
time lost	____ mins	____ mins	____ mins	____ mins	____ mins	____ mins
explanation						
Other						
explanation	❑	❑	❑	❑	❑	❑

TASK LOAD INDEX QUESTIONNAIRE

v 4/26/96

Today's Date:_____ Test Subject No. _____

❑ Instructions:
1. Administer the series of questions as indicated by the flight profiles.
2. Alert test subject "TEST SUBJECT NAME, TLX QUESTIONNAIRE".
3. Wait for acknowledgement, then go through the questions using the same pace, wording, and inflection for each administration.
4. Record results in appropriate locations.

	QUESTION	SCALE		RATINGS*							
	On a scale of 0 to 10 please assess your experience related to (appropiate activity) of the following conditions:		Timer time								
1	mental demand	(0 =low	10=high)								
2	physical demand	(0 =low	10=high)								
3	temporal demand	(0=low	10=high)								
4	performance	(0=good	10=poor)								
5	effort	(0=low	10=high)								
6	frustration	(0=low	10=high)								
			Technicians initials--								

*data entered on template in correct TLX scale

MAT-B PROCEDURE

1. If computer is off, turn the monitor on in the back.

2. Set the new date by typing in: Date. Press enter. A date prompt will come on the screen. Here is an example of a date prompt: Thu 2-06-96. If the date is correct, press enter. If the date is incorrect, enter the correct date by typing the two digit month followed by the two digit day followed by the two digit year (mmddyy). Press enter.

3. Set the new time by typing in: Time. Press enter. A time prompt will come on the screen. Here is an example of a time prompt: 14:31. If the time is correct, press enter. If the time is incorrect, enter the correct military time. Press enter.
Caution: It is very important that the correct date and time is set and that you make a note of it , because your test scores data will be filed under these criterea.

4. Select Matsb at the C:\. You may do so by scrolling through the menu with the arrows on the keypad . Press enter when Matsb is highlighted.

5. Select Matload bat in the same manner as the previous step.

6. A menu will now appear on the monitor. Use the arrow to scroll down to the heading "script file". The setting should be at 10mmed.DBT. Press enter. If it is not use the arrows to scroll through the menu and highlight the appropriate selection. **Caution:** Be sure to return the setting to that which was displayed when you first entered the system, before exiting from the system after completion of your test.

7. Select the heading "Begin Task, Normal Version", using the arrow. Press enter.

8. The Mat-b will now appear on the screen.

9. The test will run for five minutes, and at the conclusion of the test a prompt telling you that the test is over will appear on the screen.

10. To download your test information onto a disk, highlight the your five files with the advance key. **Caution**: Make sure that you only highlight those files which are yours, use the date and time to properly identify them.

11. Use the F6 key to copy/remove the files.

12. Change the C: to b: to switch to the b drive. Press enter.

Appendix J. Manufacturers and product information.

Digital Equipment Corporation 110 Spit Brook Road Nashu, NH 03062-2698	VAX 11/780 Computer
Microsoft Corporation P.O. Box 72368 Roselle, Illinois 66172-9900	MicroSoft Office Professional
NASA Langley Research Center Hampton, Virginia 23665-5225	Multi-attribute task battery
SPSS, Inc. 444 North Michigan Avenue Chicago, Illinois 60611	SPSS statistical software
Statsoft 2325 East 13th Street Tulsa, Oklahoma 74104	Statistica software
Vermont Medical, Inc. Industrial Park Bellows Falls, Vermont 05101-3122	ECG pads
Yellow Springs Instrument Company P.O. Box 279 Yellow Springs, Ohio 45387	Rectal and skin thermistors

Lamp Recommendations for
Sunlight Simulation

The following equipment is a way to test the effect of solar radiation on equipment for photo-degradation and thermal changes. The spectral output of the electric lamps should simulate the ultraviolet, light, and infrared radiation from sunshine on the terrestrial surface.

This system consists of a bank of HR400RDXFL33 mercury lamps mounted as close as possible to each other and requiring one lamp per square foot of area to be covered. Since these lamps are made with a built-in reflector, a distance of up to 12 feet will be necessary in order to smooth the beam coming from the lamps. The distance should be adjusted until little or no drop-off is observed at the edges of the target.

The spectral distribution for this lamp yields 8% below 400 nm, 46% between 400 nm and 800 nm, with a total radiated output of 135 watts. While this distribution does not quite meet the requirements of MIL-STD-810C, Method 505.1, is comes quite close, being about 25% more severe. It is the closest way we know of to approach the requirements of MIL-STD-810C at a reasonable cost.

The correlated color temperature of the HR400RDSFL33 lamp is 3900k, x = .388, y = .384, initial lumens are 15,500, mean lumens are 9,950 over 24,000 hours rated life. The spectral distribution curve for the lamp is enclosed

Wavelength	Less than 380 nm	Between 380-780	Above 780 nm	Total
MIL-STD-810C Watts/Sq.Ft.	4-7	37.5	50-72	104
HR400RDXFL33 Watts/Sq.Ft.	11	62	62	135

JRM/mos 10/26/90